DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-6

AQUATIC DISPOSAL FIELD INVESTIGATIONS EATONS NECK DISPOSAL SITE LONG ISLAND SOUND

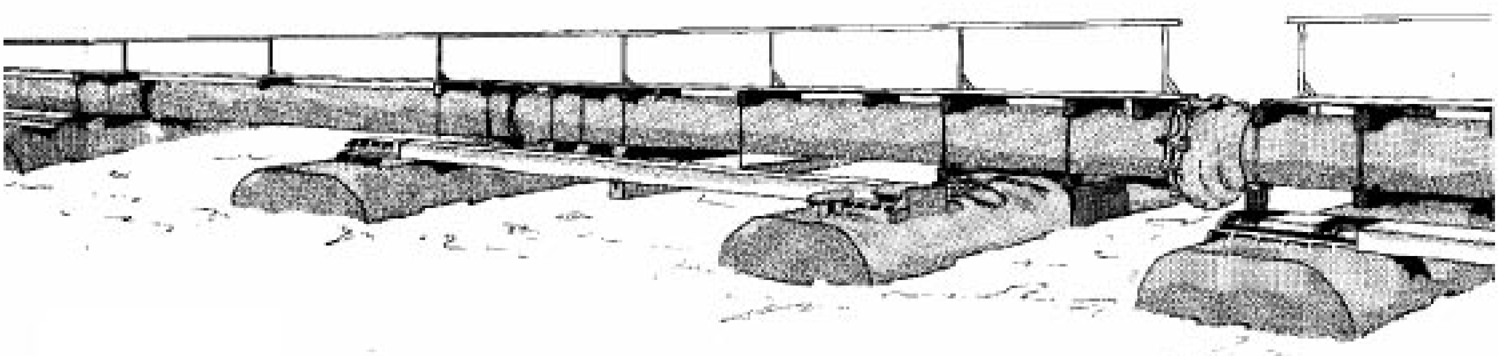
AN ENVIRONMENTAL INVENTORY

by

S. P. Cobb, J. R. Reese, M. A. Granat
B. W. Holliday, E. H. Klehr, J. H. Carroll

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

May 1978
Final Report



Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under DMRP Work Unit No. 1A06

AQUATIC DISPOSAL FIELD INVESTIGATIONS
EATONS NECK DISPOSAL SITE
LONG ISLAND SOUND

Appendix A: Investigation of the Hydraulic Regime and the Physical Characteristics of Bottom Sedimentation

Appendix B: Water-Quality Parameters and Physicochemical Sediment Parameters

Appendix C: Predisposal Baseline Conditions of Benthic Assemblages

Appendix D: Predisposal Baseline Conditions of Demersal Fish Assemblages

Appendix E: Predisposal Baseline Conditions of Zooplankton Assemblages

Appendix F: Predisposal Baseline Conditions of Phytoplankton Assemblages

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

15 June 1978

SUBJECT: Transmittal of Technical Report D-77-6

TO: All Report Recipients

1. The technical report transmitted herewith contains the results of several research efforts (Work Units) undertaken as part of Task 1A, Aquatic Disposal Field Investigations of the Corps of Engineers' Dredged Material Research Program. Task 1A was a part of the Environmental Impacts and Criteria Development Project (EICDP), which had as a general objective the evaluation of the magnitude and extent of effects of disposal sites on organisms and water quality, including benthic recolonization rates and extents. This report is a summary of the physical, chemical, and biological baseline studies conducted at the Eatons Neck disposal site in Long Island Sound. This disposal site is one of five disposal sites studied in various geographical regions of the United States.

2. This report is Aquatic Disposal Field Investigations, Eatons Neck Disposal Site, Long Island Sound; An Environmental Inventory, Waterways Experiment Station Technical Report D-77-6. Six contractor-prepared appendices (A-F) relative to this main report have been published separately. This main report provides additional results, interpretations, and conclusions not found in the appendices and provides a comprehensive summary and synthesis of the entire study.

3. The purpose of the Eatons Neck study was to determine the physical, chemical, and biological effects of open-water disposal of dredged material in western Long Island Sound. However, because of local opposition to the proposed research and dredging operation, the study was terminated at the conclusion of the baseline studies. The resulting data were used to describe the environment at the disposal site and surrounding study areas and to make limited assessments of the effects of over 70 years of disposal at the site. The studies provided data on the hydraulic regime, meteorology, sediment chemistry, water chemistry, plankton, benthos, and demersal fish and shellfish, including American lobster, at the site.

4. Conclusions based on the data presented are (a) the Eatons Neck disposal site is an acceptable site for dredged material disposal since

transport of material from the site is minimal; (b) it appears that any effects of dredged material disposal at the site on nutrients, metals, and other chemical variables in the sound are minimal and are often overshadowed by the effects of sewage effluents and river discharges; (c) significant adverse effects on the benthic community of the site were not evident; and (d) the presence of dredged material and other substances placed at the site may be related to the regional importance of the site as a commercial lobstering ground.

5. Results of the Eatons Neck research will be useful in evaluating the environmental impacts of any future disposal activities that may be authorized at the site, developing any needed management plans for the site, evaluating effects of other Long Island Sound disposal operations, and designing additional environmental studies of the site.

John L. Cannon

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report D-77-6	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AQUATIC DISPOSAL FIELD INVESTIGATIONS, EATONS NECK DISPOSAL SITE, LONG ISLAND SOUND; AN ENVIRONMENTAL INVENTORY		5. TYPE OF REPORT & PERIOD COVERED Final Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) S. P. Cobb, J. R. Reese, M. A. Granat, B. W. Holliday, E. H. Klehr, J. H. Carroll		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DMRP Work Unit No. 1A06
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE May 1978 13. NUMBER OF PAGES 119
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Appendices A through F to this report were reproduced separately (see list of appendices on inside of front cover).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dredged material	Field investigations
Dredged material disposal	Sedimentation
Eatons Neck disposal site	Waste disposal sites
Environmental effects	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of the Dredged Material Research Program being conducted by the U. S. Army Engineer Waterways Experiment Station, an investigation of the environmental effects of open water dredged material disposal was initiated at the Eatons Neck Disposal Site in central Long Island Sound, New York. However, because of local political and public opposition to the dredging project, the field investigation was terminated after Phase I, a 12-month baseline survey of the disposal site and surrounding area. Phase I data, therefore, were used to describe environmental conditions at the Eatons Neck Disposal Site as they were four years after cessation of disposal operations. Dredged material, building rubble, and other materials were dumped at the site for about 70 years (1900 to 1971); 9,841,000 m^3 of dredged sediments were placed at the site from 1954 to 1971.

(Continued)

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

Results of hydrodynamic, bathymetry, and sediment studies showed no evidence of dispersion of dredged material from the site. Thus it appears that the Eatons Neck site is suitable, from a confinement standpoint, for the disposal of dredged sediments. Measured current velocities were typically <30 cm/sec 2 m above the bottom; net tidal displacement of water was to the west or southwest at speeds <6 cm/sec. Bathymetric shielding by Cable and Anchor Reef contributed to the reduced flow at the site.

Water chemistry data indicated that there were various types of spatial gradients in the central sound. However, it appeared that factors other than the presence of dredged material at the disposal site, e.g., river discharges containing sewage effluents and other chemicals, could explain these gradients. There appeared to be no major differences in chlorophyll a, dissolved oxygen, and dissolved and suspended metals between reference station A and disposal site station DSA. Particulate carbon and nitrogen were higher at the reference station than at the disposal site in March and May. However, interpretations of the water chemistry data are unclear because daily temporal variation was not adequately separated from spatial variation due to a lack of synoptic data.

There were no significant differences between reference station A and the disposal site stations for sediment mineralogy, bulk sediment, and interstitial water metals (with the possible exception of zinc and manganese), oil and grease, and cation exchange capacity. Ammonia, organic carbon, organic nitrogen, and pH, however, were all higher in the sediments at the disposal site than at the reference station. Sediments at the reference station were more fine grained in the upper 10 cm than at the disposal site. These differences are probably due to the larger amounts of organic matter in dredged material at the disposal site. No dissolved oxygen depletion was noted in the bottom water at the disposal site, however.

It appears, in summary, that any effects of the presence of dredged material at the site on nutrients, metals, and other chemical variables in the central sound are minimal and are probably overshadowed by effects of sewage effluents and other river imputs.

There were few significant differences in the abundance and composition of the benthic macrofauna between sampling stations located on the dredged material deposit and the reference stations. Areally the mud benthic assemblage extended across most of the disposal site and was widely present outside of the site boundaries. The relatively low abundance and diversity of benthos in the mud assemblages were not confined to the dredged material deposit. This trend suggests that these conditions were either natural or a result of perturbations other than the disposal of dredged material. The sand benthic assemblages located on reefs adjacent to and partially within the disposal site had greater abundances of organisms than the mud assemblage.

Plankton variability and the small number of samples collected precluded any detailed analyses. However, no gross differences were observed in the plankton between the disposal site and reference stations.

The Eatons Neck Disposal Site was found to be a valuable habitat for fishery resources, especially American lobsters. Commercially important species such as winter flounder were equally or more abundant at the disposal site than at the reference station. The disposal site is the major commercial lobstering ground in Long Island Sound. The abundance of suitable sediments (mainly dredged material), building rubble, and other materials for burrow constuction is probably responsible for the abundance of lobsters; the production of benthic organisms, the lobsters' diet, must also be adequate to support the abundant population. Accumulation of heavy metals by lobster as compared to the reference area was not noted at this site.

PREFACE

The investigation reported herein was conducted as part of the Environmental and Criteria Development Project of the Dredged Material Research Program (DMRP). The DMRP is sponsored by the Office, Chief of Engineers, and was authorized by the Congress in the 1970 River and Harbor Act. The U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, is assigned the task of conducting the DMRP. An interdisciplinary team of the Environmental Laboratory (EL), WES, is responsible for planning and managing the DMRP.

The research at the Eatons Neck disposal site was conducted by contractors. The Department of Geology and Geophysics of Yale University performed the physical studies; the Marine Sciences Research Center, State University of New York at Stony Brook, performed the chemical studies; and the biological studies were conducted by the New York Ocean Science Laboratory. The summary report is based on the contractors' evaluations of the data and additional analyses and interpretations of the data by the WES.

The report was prepared under the general supervision of Dr. John Harrison, Chief, EL, and Dr. R. T. Saucier, Special Assistant, EL. Dr. R. M. Engler was project manager, and Mr. J. R. Reese was site manager and contributed to this report.

Mr. S. P. Cobb was editor of the summary report. Various technical sections were prepared by the following persons: physical studies, Messrs. M. A. Granat and B. W. Holliday; chemical studies, Dr. E. H. Klehr; benthic studies, Mr. Cobb; plankton studies, Messrs. Reese and Cobb; and fishery studies, Messrs. Reese and J. H. Carroll. Statistical analyses of the data were done by Mr. A. D. Magoun.

Commanders and Directors of the WES during the period of this investigation were BG E. D. Peixotto, CE; COL G. H. Hilt, CE; and COL J. L. Cannon, CE. Technical Director of the WES was Mr. F. R. Brown.

CONTENTS

Note: Appendices A through F to this report were reproduced separately (see list of appendices on inside of front cover).

AQUATIC DISPOSAL FIELD INVESTIGATIONS
EATONS NECK DISPOSAL SITE
LONG ISLAND SOUND: AN ENVIRONMENTAL INVENTORY

PART I: INTRODUCTION

Background

1. The U. S. Army Corps of Engineers (CE) has responsibility for the dredging and disposal of approximately 230,000,000 m^3 of dredged material annually of which about 191,000,000 m^3 per year are disposed of in the open waters of oceans, bays, estuaries, and rivers and lakes.[1] The environmental and engineering problems associated with open-water disposal as well as most other aspects of dredging and disposal were investigated by the Dredged Material Research Program (DMRP). The DMRP is a comprehensive program of research and experimentation, with its major objectives being to provide definitive information on the environmental impact of dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource.

2. The Eatons Neck Aquatic Disposal Field Investigation was a part of the Environmental Impacts and Criteria Development Project (EICDP), one of four major research projects within the DMRP. The goal of the field studies was to evaluate effects of aquatic disposal on organisms and water quality, including the significance of physical, chemical, and biological factors that influence the rate of disposal site recolonization by benthic animals.

Site Selection

3. A nationwide survey of open-water dredged material disposal sites was conducted to select four research sites that were representative of various aquatic environments and dredging operations. Within

the North Atlantic region, Long Island Sound was selected as a study area because the dredged material volumes and dredging and disposal methods within the sound are typical of the region.*

4. Prior to final site selection, use of 16 of the 20 Long Island Sound disposal sites was discontinued by mutual agreement of several regional, State, and Federal agencies. This action left the Eatons Neck, Cornfield Shoals, New Haven, and New London sites as possible research sites. The latter two sites were eliminated from consideration since they had ongoing dredged material studies. The Eatons Neck site was selected for study in lieu of the Cornfield Shoals site because it had more material scheduled for disposal, a compatible dredging disposal schedule, better accessibility, and closer proximity to research groups.

Purpose and Scope

5. The original purpose of the Eatons Neck research was to evaluate the impacts of dredged material disposal on water and sediment quality and biological communities, in particular the rate and extent of benthic recolonization of the dredged material deposit. A comprehensive three-phase research program was designed and implemented to identify the cause-and-effect relationships associated with the ecological impacts of open-water disposal: Phase I - a 12-month baseline survey; Phase II - monitoring of an experimental dredged material disposal operation; and Phase III - one-year postdisposal monitoring effort.

6. Local political and public opposition to the dredging project and the proposed research resulted in cancellation of the study at the end of Phase I. Consequently, this report presents a description of environmental conditions at the Eatons Neck disposal site as they were approximately four years after cessation of disposal operations. Limited comparisons are also made between the disposal site and reference areas regarding effects of past dredged material disposal.

---

* J. R. Reese, et al., "Nationwide Survey of Existing Dredged Material Disposal Sites," unpublished memo, 1974, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi.

Research Approach

7. A multidisciplinary approach was taken in the baseline investigations to provide background data on environmental characteristics of the study area. There were three categories of baseline investigations: physical, chemical, and biological. A separate contractor was responsible for the research in each category. The Department of Geology and Geophysics, Yale University, conducted the physical studies; the Marine Sciences Research Center, State University of New York at Stony Brook, conducted the chemical studies; and the biological studies were carried out by the New York Ocean Science Laboratory. Concomitant chemical and biological data were collected whenever possible; scheduling and coordination problems, however, resulted in little comparable information. Results and conclusions given in this report are based on contractors' data and additional analysis and interpretation of the data by WES.

8. Dredged material disposal was expected to have a primary effect on bottom fauna. Hence, assessment of benthic assemblages at the disposal site and in adjacent reference areas was emphasized in the field work. On the contrary, water chemistry studies were directed toward measuring horizontal and vertical patterns of concentration of nutrients, metals, and other variables over much of the western sound as well as the disposal site. Sediment chemistry investigations were confined to the disposal site and reference stations so that relationships between benthic impacts and sediment chemistry changes could be evaluated. Physical studies were oriented toward defining water circulation patterns, current velocities, and the movement of the dredged material.

9. Chemical and biological sampling began in October 1974 following a benthic pilot survey in March 1974.* Hydraulic and geological field work commenced in July 1974. These studies continued through mid-April 1975 when an experimental disposal site was selected and the

---

* D. K. Serafy, "Eatons Neck Dredged Material Disposal Site, Long Island Sound - Benthos," unpublished preliminary report, 1974, prepared by New York Ocean Science Laboratory for the U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississipi.

sampling scheme was changed. Sampling continued through late May and early June using the revised design. A detailed account of the various sampling regimes is contained in Part III: Methods and Materials.

10. Baseline studies at Eatons Neck were not originally intended as an environmental description of the disposal site per se, but were intended to generate background information for monitoring effects of an experimental disposal operation. However, the available data can be used to describe the general environment of the disposal site and to a limited extent for assessing effects of past disposal.

PART II: DESCRIPTION OF THE STUDY AREA AND DISPOSAL SITE

Study Area

11. The Eatons Neck site is located in western Long Island Sound, New York. The sound is a moderately stratified estuary[2] with a two-layered water circulation system. There is a net eastward movement of surface water into Block Island Sound and a net westward movement of bottom water into New York Harbor through the East River. This large-scale estuarine circulation pattern is superimposed on the more dominant tidal flow. Tidal transport is characterized by horizontal movement along the main axis of the sound. The semi-diurnal tides range in height from 0.8 to 2.2 m. Circulation and mixing are influenced by winds and freshwater discharge from the Connecticut, Mystic, Thames, and Housatonic Rivers.

12. Long Island Sound is a settling basin for sediments discharged by rivers or transported from the continental shelf in bottom waters entering the eastern end of the sound. Sixty percent of the sound is covered by homogeneous, silty sediments mainly in water deeper than 10 m. Coarser sand and gravel sediments occur in waters shallower than 10 m, mainly nearshore and on reefs. Harbors and inner bays have fine-grained sediments.

13. Nutrient levels in the sound exhibit a west-east gradient, probably associated with the discharge of the East River.[3, 4] The water column is stratified in summer with a maximum vertical temperature gradient of about 5°C.[5] Small vertical gradients in nutrients and salinity are also associted with thermal stratification. Dissolved oxygen levels, while vertically uniform during most of the year, become depleted in bottom waters during stratification.[6]

14. The sound is fished commercially for numerous species of fish and shellfish, the most important being winter flounder, menhaden, herring, summer flounder, American lobster, and oysters.[7] Lobstering is important at the Eatons Neck site. Recreational fishing occurs for striped bass, black sea bass, bluefish, and weakfish.

Disposal Site

15. The Eatons Neck disposal site is located in the western basin of Long Island Sound, approximately centered at $41^{o}00'$ N and $73^{o}30'$ W and lying midway between the Connecticut and Long Island shores (Figure 1). The site originally encompassed 5.2 square km of surface water, but was extended 2.6 km to the north, thereby doubling its size, so that an area free of wrecked ships could also be investigated. The northward extension included much of the old Norwalk disposal site. Water depths ranged from about 12 m at Cable and Anchor Reef to 55 m near the southern border of the site. Sediments at the site were primarily fine textured except in shallow reef areas where coarser sandy sediments occur.

16. The site was used for dredged material disposal for about 70 years beginning around 1900. Disposal records for the 1954 to 1973 period indicate that 9,841,000 m^3 of dredged sediments were dumped at the site (Table 1). Several derelict ships, building rubble, and other materials have also been disposed of at Eatons Neck.

17. Most of the dredged material placed at the site was from maintenance dredging of harbors along the shores of the sound. No detailed records were kept of the types of sediments dredged, but "mud" is generally listed as the sediment type. The principal method of disposal at Eatons Neck was by barge.

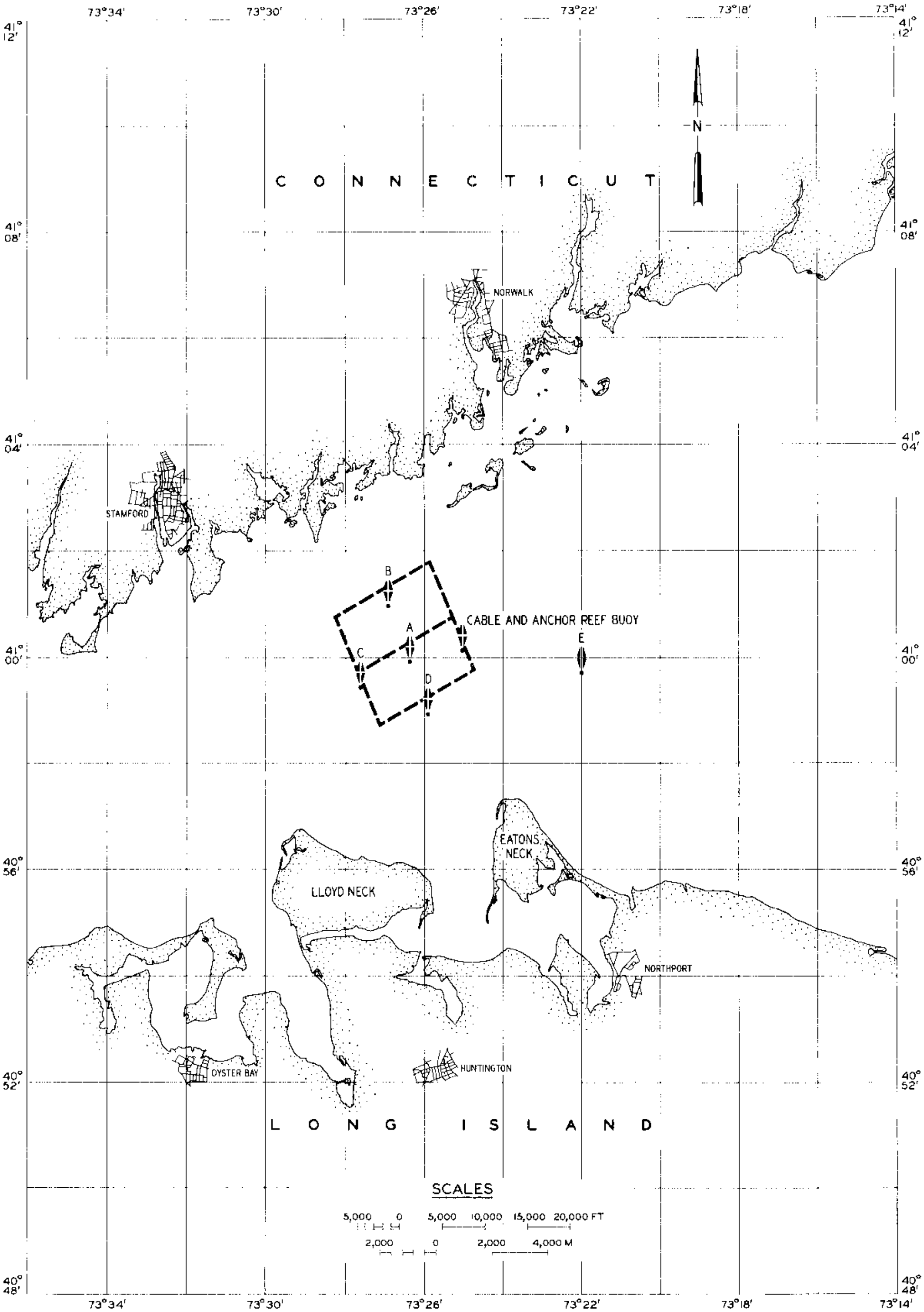


Figure 1. Locations of the Eatons Neck Disposal Site, the northern extended area, and the marker buoys

PART III: METHODS AND MATERIALS

Physical Studies

18. The field methods used in accomplishing the objectives of the physical studies at the Eatons Neck site were (a) bathymetric and subbottom acoustic-reflection profiling; (b) bottom sediment sampling; (c) bottom photographs and in situ penetration tests; (d) current meter and wave gauge deployments; (e) vertical transmissivity measurements; and (f) salinity and meteorological observations. In most instances, stations were located by the use of horizontal angles measured with a sextant or a surveying quintant from the research vessel. Positioning was estimated to be accurate to within a few metres.

19. Three bathymetric surveys were conducted by the New York District Corps of Engineers: one in 1961 using horizontal sextant and two surveys (spring 1974 and fall 1976) using a Ross Fine Line fathometer interfaced with a Cubic D. M. 40 microwave positioning system to determine the bottom topography at the Eatons Neck disposal site and adjoining area (Figure 2). Bathymetric contour maps were compared to determine areas of erosion and deposition and to obtain a qualitative assessment of the general bottom stability.

20. Yale University performed 19 north-south acoustic-reflection profiles (Figure 2) with a Raytheon 1000 RTT profiling system. This unit makes use of a 200-kHz pulse for high resolution of bottom topography and a 7-kHz pulse that penetrates the sediments to detect subbottom structures. These acoustic-reflection profiles were useful in identifying the principal sediment types (sand/gravel, silt with various amounts of sand, and dredged material) and defining their distribution.

21. To supplement the acoustic classification of sediments and to determine the grain-size distributions, 108 bottom sediment samples (Figure 3) were collected over a five-month period (July-November 1974) with either a gravity corer or a Van Veen grab sampler. Additional acoustic-reflection profiles were made at each sample site to aid in correlation of sediment type with the acoustic record. A sediment-

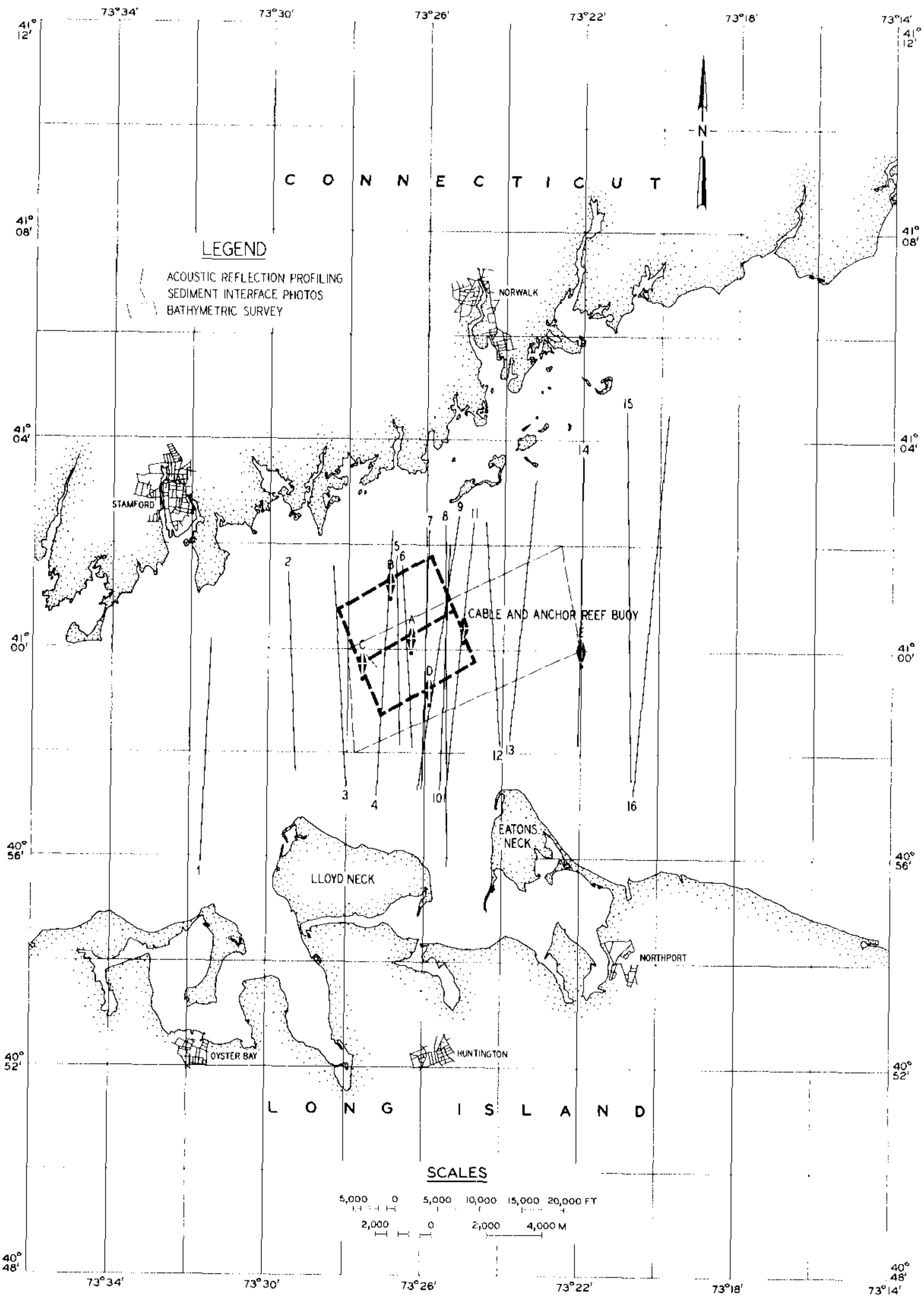


Figure 2. Locations of bathymetric surveys, acoustic reflection profiling, and sediment interface photography conducted from November 1974 to June 1975

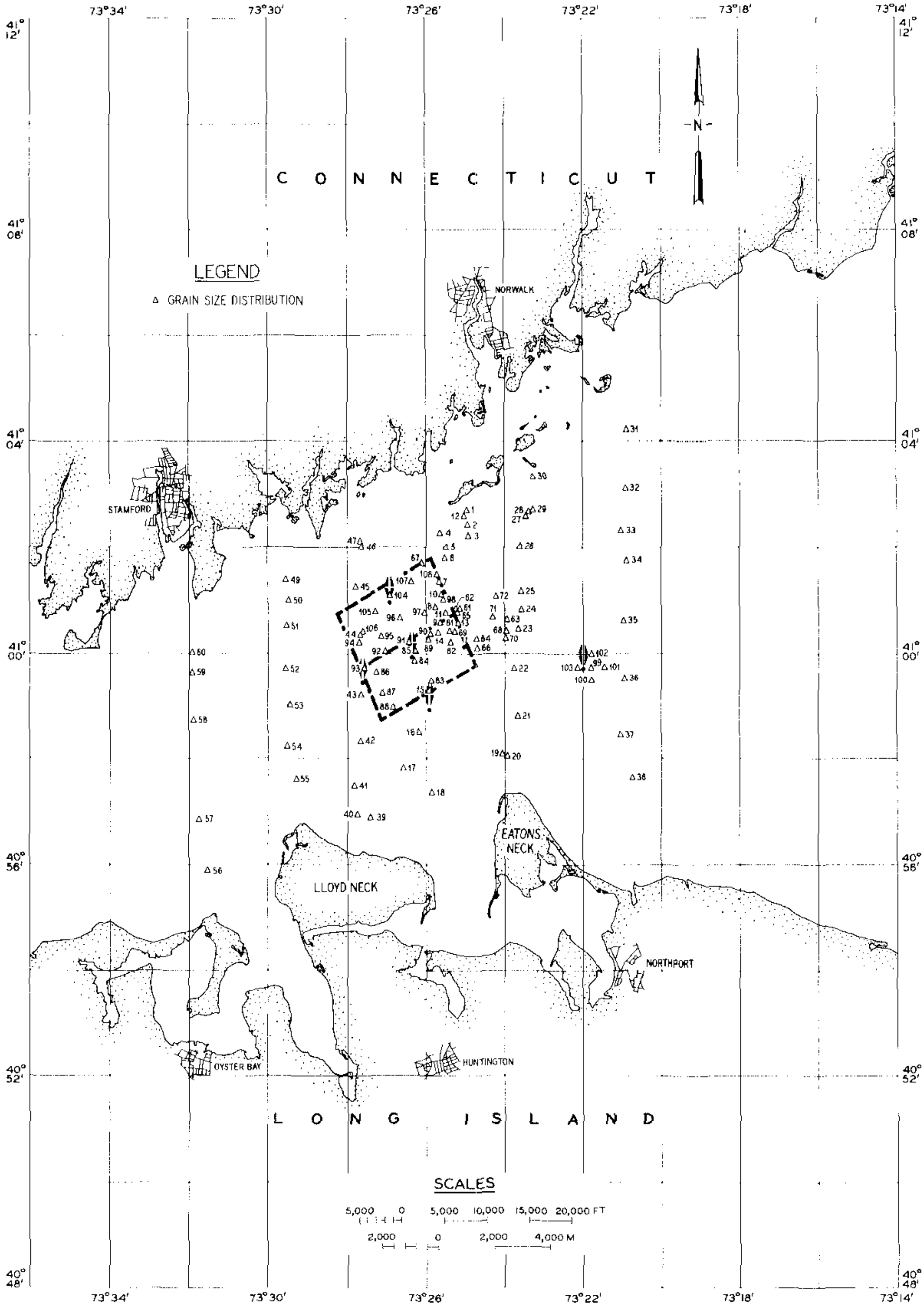


Figure 3. Locations of sediment samples used for grain-size analysis

water interface profile camera was used (March 1975) to aid in identification of general sediment characteristics and layering and benthic organisms. Diver photographs of the bottom (September 1975) and in situ penetration tests were used to further verify the sediment data prior to the preparation of sediment distribution maps.

22. The hydraulic regime was investigated with current meters and a wave gauge. Two types of current meters were employed on taut line moorings 2 m off the bottom: a Braincon 381 savonious rotor current meter that recorded average current speed and direction over successive 20-minute intervals and a General Oceanics model 2010 wand-type meter that recorded instantaneous current speed and direction at fixed time intervals. Near-bottom currents were monitored at 16 stations within and adjacent to the disposal site (Figure 4) for approximately 320 days. Information was also obtained from 10 to 22 January 1975 from a vertical array of four current meters within the disposal site (Station EN-A).

23. The long-term or net flow at each current meter station was determined by progressive vector summation. Progressive vector diagrams prepared for successive tidal cycles were used to summarize gross water flow characteristics. Polar histograms and frequency of occurrence tables were used to summarize the short-term or time-varying flow conditions. Shading on histograms (Appendix A, Plates 19-30)* indicates the frequency or probability of occurrence in 5 cm/sec speed and 36^{o} direction intervals: darkest shading indicates $5\% < P < 7.5\%$; intermediate shading $2.5\% < P \leq 5\%$; lightest shading $0 \leq P \leq 2.5\%$. Frequency of occurrence tables (Tables 2-10) indicate the actual percent occurrence for the individual speed-direction intervals, the total percent for the direction (column) and speed (row) interval, and the percent velocities greater than the specified interval.

---

* Appendix references are to the contractor-prepared reports of the various research studies. A listing of the titles of the appendices, which were published separately, is given on the inside of the front cover of this report.

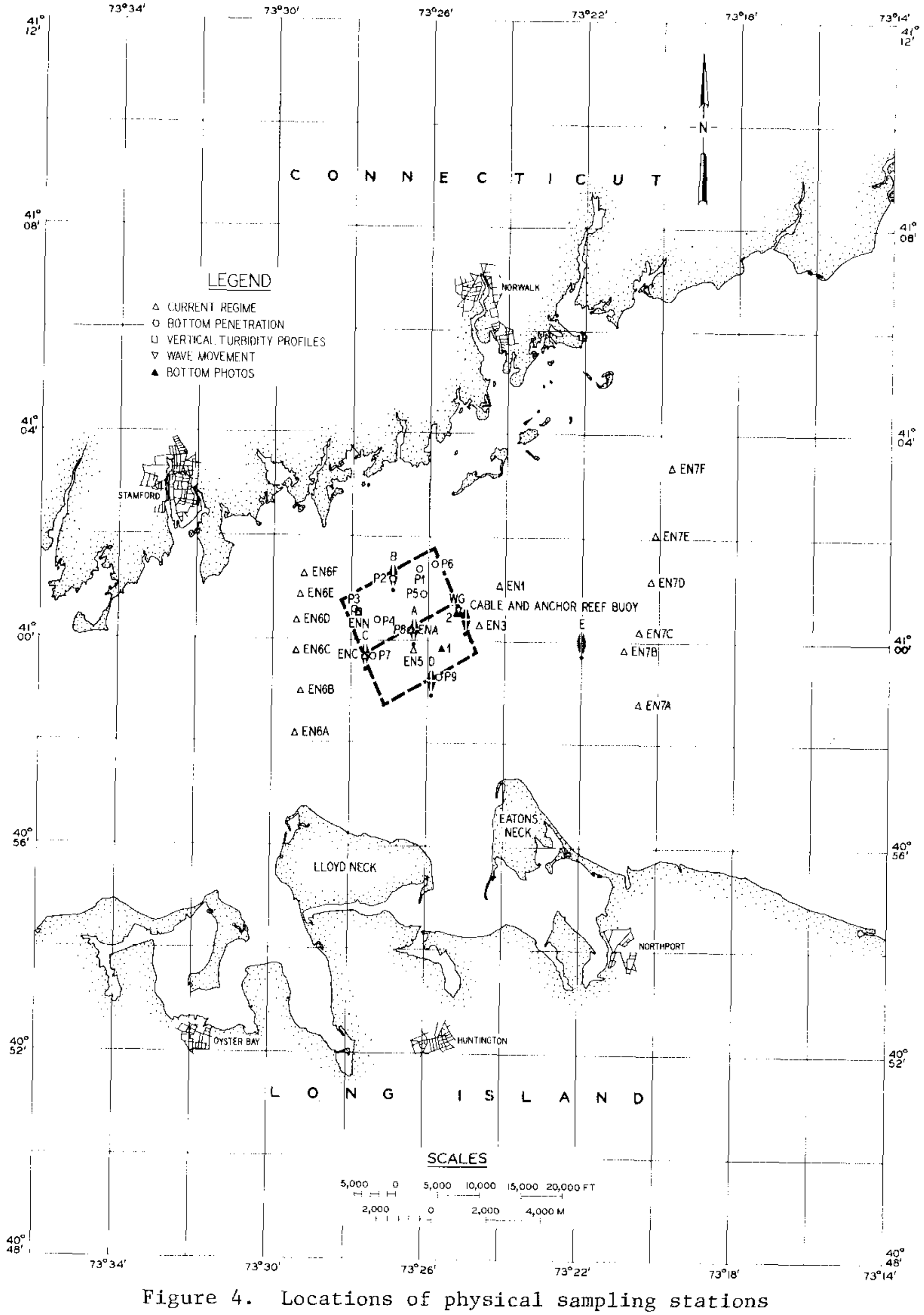


Figure 4. Locations of physical sampling stations

24. A theoretical analysis of the current meter records was made to further evaluate the processes involved in producing flow characteristics (Appendix A). The instantaneous or measured current v(t) at any station was considered to represent the sum of a sinusoidally varying term U(t) (the astronomically induced tide), a steady or constant term $U_o(t)$ equated with estuarine circulation (the net displacement or average velocity over one or more complete tidal cycles), and the residual or unaccounted for current u'(t):

$$v(t) = U(t) + U_o(t) + u'(t) \qquad (1)$$

The time scale used to delimit the terms is chosen both for operational convenience according to the desired physical interpretation and the length of available record.

25. Harmonic analyses using linear regression techniques were performed on the north-south and east-west components from three of the near-bottom current-meter stations (EN-A, EN-C, and EN-N) to obtain the astronomically induced tidal velocity components. Periodograms were also calculated to determine energy density. The difference between the observed current and that predicted from the harmonic analysis was considered to be the nontidal flow, i.e., the steady or constant term plus the residual current. Progressive vector summation over successive tidal cycles was one technique used to determine the constant term. A second, more accurate method used for removing tidal components was to pass the total current time series through an appropriate low-pass digital filter that eliminated all components with periods less than 24 hr. The residual current, considered to be the fluctuating velocity component or tidal stream turbulance, is the difference between the predicted astronomical velocity and the constant term from the observed velocity.

26. A Bass model WG 100 wave recorder was deployed between 19 February and 27 March 1975 to investigate the influence of storm-generated waves on bottom circulation. The wave recorder, placed in 13.7 m of water near Cable and Anchor Reef (Figure 4), continuously recorded water pressure for three minutes each hour. Although short-wavelength waves were not detected because of attenuation at this

depth, the information was still in accord with the objective of monitoring waves of sufficient wavelength to produce appreciable particle velocities on the bottom. Small-amplitude wave theory was employed in the analysis of the pressure data to obtain wave characteristics and associated horizontal bottom particle velocities. Since the wave characteristics were not expected to change significantly between the disposal area and Cable and Anchor Reef, the horizontal particle velocities within the disposal site were calculated from the obtained record in terms of increased depth and the wave period.

27. To evaluate the interaction between the bottom sediments and the water flow characteristics, vertical transmissivity profiles were taken with a 10-cm path length white light optical transmissometer and pressure sensor. Observations were taken every 30 min from 1800 hr on 24 March until 1600 hr on 25 March 1975 at Station EN-N (Figure 4). Wind velocity was simultaneously measured with a shipboard anemometer. Water flow characteristics 2 m above the bottom were monitored with a General Oceanics current meter recording the flow every 0.94 minutes. Fluctuating velocity, i.e., residual current described previously in paragraph 25, was determined. Laboratory calibration of the transmissometer was done by resuspending weighed quantities of sediment collected from the study area. An empirical relationship relating percent light transmittance to suspended sediment concentration was derived.

Chemical Studies

28. Nineteen water chemistry stations were sampled to determine spatial and temporal distribution patterns of chemical variables at the Eatons Neck site and in the western sound (Figure 5). Monthly sampling was conducted from October 1974 through May 1975. In addition, stations DSA and DSB were sampled from March through May 1975. Diurnal sampling efforts were conducted at stations A-H, J, and K in October and November 1974 to evaluate tidal effects.

29. The Plunket System, a shipboard data-acquisition apparatus,

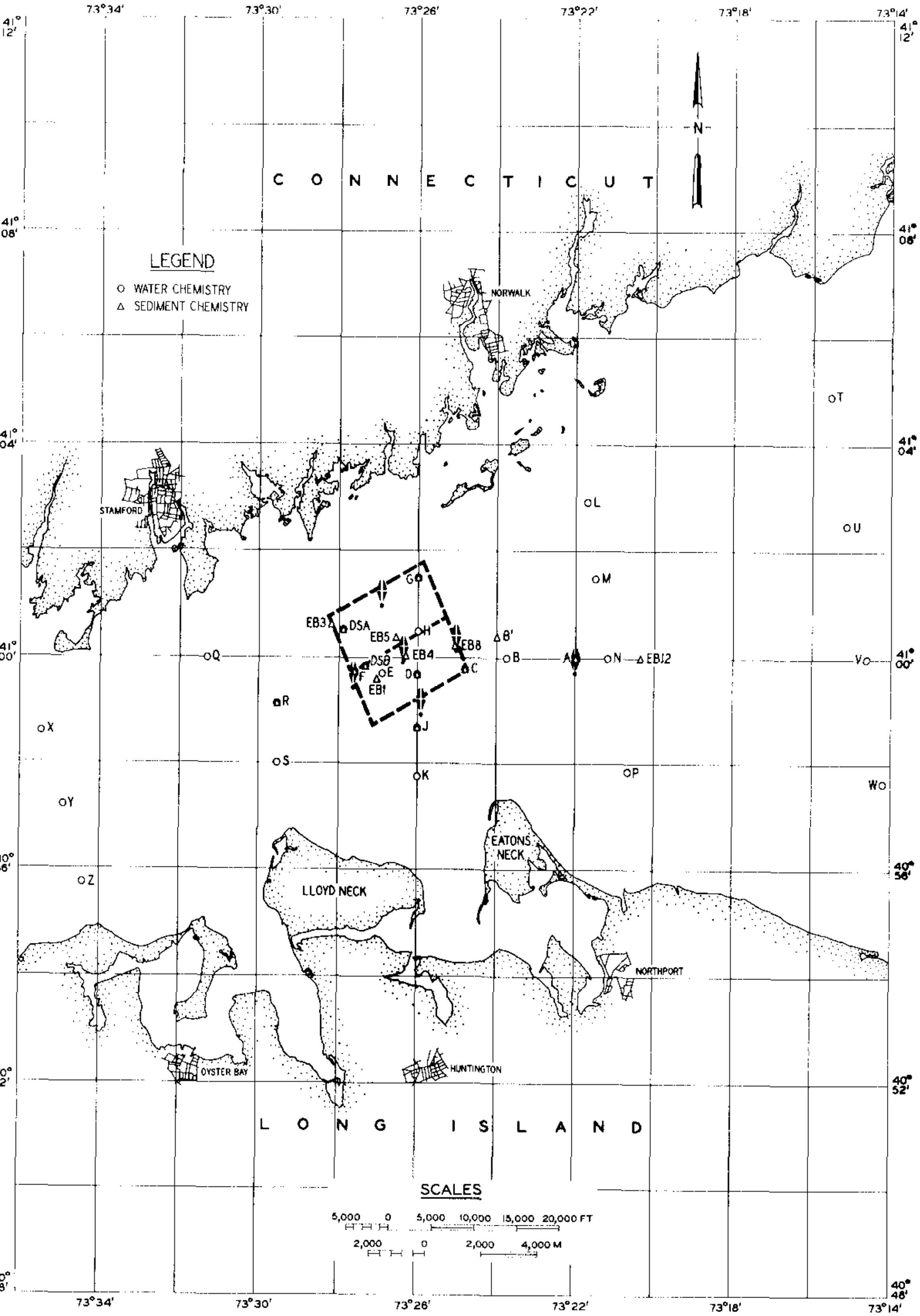


Figure 5. Locations of water and sediment chemistry sampling stations

was used to measure water temperature, salinity, dissolved oxygen, and chlorophyll _a_ in the field and to obtain water samples for the analysis of other variables. Samples for heavy metal analysis, however, were taken with a Niskin water bottle. Vertical profiles were made at each station and replicate samples were collected at selected stations.

30. Sediment samples were collected at 17 stations (Figure 5) using a Benthos gravity core with cellulose acetate butyrate liners. Cores were sectioned (upper 10 cm, remaining core in 20 cm sections) aboard ship; pH was measured; and cores were stored at $5^{o}C$ for analysis.

31. The water and sediment chemistry variables measured and the analytical instruments and procedures used for generating the data are summarized in Table 11. Detailed methods and materials are given in Appendix B.

Biological Studies

Benthos

32. In October 1974, samples were taken at 36 benthic stations (Figure 6) using a 0.1-m^2 Smith-McIntyre grab* and were analyzed for species composition and abundance. This information and data from the physical survey were used to select permanent sampling stations for macrofauna, meiofauna, epibenthos, fish, and sediment chemistry.

33. Twelve stations (EB1-EB12, Figure 7) were sampled for macrofauna in December 1974 and January, February, and April 1975 using a Smith-McIntyre grab; three replicate samples were collected per station. In preparation for monitoring the proposed experimental disposal operation, 15 different macrofauna stations (A1-A15, Figure 7) were established near the western corner of the site and were sampled monthly as described above from 22 April through 19 June 1975. Sampling at all other benthic stations was discontinued, except at reference station EB11, after April. In addition, epibenthic macrofauna was surveyed at stations EB3, EB4, EB9, and EB11 in December, January, February, and May

---

* Ibid.

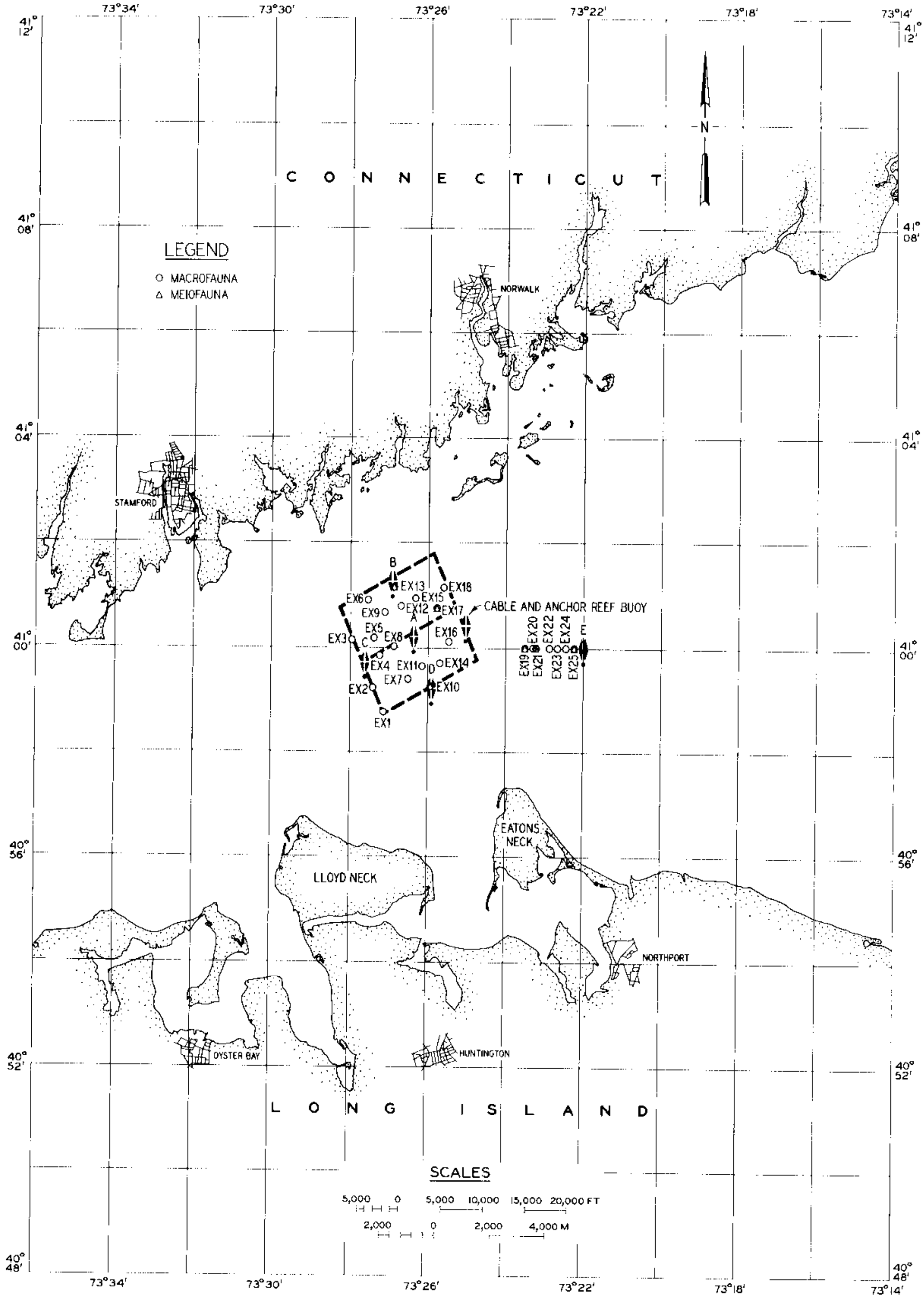


Figure 6. Locations of macrofauna and meiofauna stations sampled October 1974

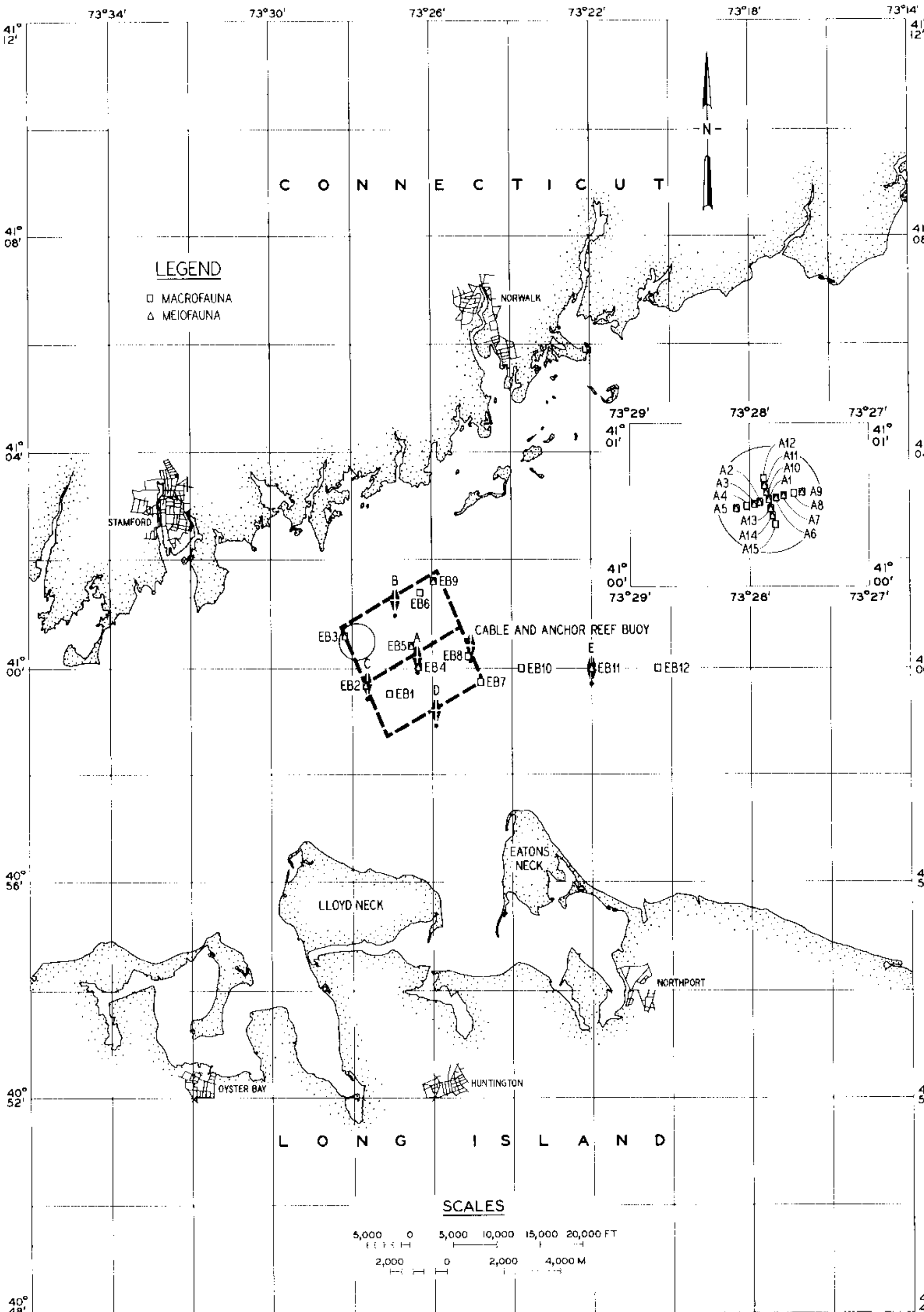


Figure 7. Locations of macrofauna and meiofauna stations sampled December 1974 through June 1975

with an epibenthic sled equipped with a 2-mm-mesh net. Sediment subsamples for meiofaunal analysis were collected from one Smith-McIntyre grab collected at stations EB3, EB4, EB9, EB11, and A1-A14, utilizing a Hope Corer (3.5-cm diameter).

34. Macrofauna was separated from the sediments by sieving through a 0.5-mm-mesh screen. Meiofauna was defined as those organisms that passed through the 0.5-mm-mesh screen, but were retained on a 0.0625-mm-mesh screen. Ash-free dry-weight biomass, density of organisms, and species composition were determined for each macrofaunal sample. Only the latter two parameters were measured for meiofauna and epibenthic sled samples.

35. Inverse and normal classification procedures involving the Bray-Curtis Dissimilarity Index and flexible sorting strategy[8] were utilized for defining macrofaunal station group and species group distribution patterns. Nodal analysis of abundance, constancy, and fidelity data[9] was used to evaluate relationships between station groups and species groups. The Shannon-Weaver Diversity Index and related species richness and evenness parameters[10] were also calculated for the macrofaunal data. A complete description of methods and materials for the benthic studies are presented in Appendix C.

36. Additional analyses of the benthic data were conducted by the Waterways Experiment Station (WES). A parametric two-way analysis of variance (ANOVA) was performed on macrofaunal total density and number of taxa data for the December through April collections at stations EB1-EB10. A logarithmic transformation of the raw data was made prior to the analysis. This test was conducted to compare the main effects of sampling time and station for macrofaunal assemblages within the disposal site boundaries as defined by numerical classification. Also, an index of abundance, calculated by dividing the total number of individuals of a species by the number of stations in the assemblage, was used to define dominant species in an assemblage. Comparisons between disposal site stations and reference stations were made using one-way ANOVA of logarithm-transformed total density and number of taxa data for each sampling period from December 1974 through April 1975.

Phytoplankton

37. Phytoplankton was sampled approximately monthly from October 1974 through June 1975 at stations EN1, EN2, and EN3 (Figure 8). Samples at each station were collected with a Niskin bottle at three depths (surface, mid-depth, bottom). A vertical net tow was also made at each station to supplement the Niskin bottle data. Cell counts and species composition were determined for each sample. Primary productivity was estimated three times at stations EN2 and EN3 using radioactive carbon techniques. Complete phytoplankton sampling and analysis methods are contained in Appendix D.

Zooplankton

38. Zooplankton samples were collected monthly from October 1974 through June 1975 at stations ENDSA, ENA, ENB, END, EN1, EN2, and EN3 (Figure 8). Five- to ten-min surface, mid-depth, and bottom tows were made at each station using Bongo nets of both 202-μ and 363-μ mesh equipped with a flow meter. Diurnal sampling was also conducted at selected stations and times. Samples were analyzed for species composition and population density. Details of the zooplankton sampling and analysis methods are presented in Appendix E.

Fish

39. One trawl sample of 15-min duration was taken monthly from November 1974 through June 1975 at stations EF1, EF3, and EF4 (Figure 9). Sampling at station EF2 was discontinued after 5 months due to the presence of bottom obstructions. A 9-m mouth diameter, semi-balloon otter trawl was utilized. Catches were analyzed for species composition, number, weight, lengths, and sex (in the case of lobsters only). Fish stomachs were removed from dominant fish species for diet analysis.

40. At WES, Friedman's nonparametric ANOVA was used to evaluate differences in fish catches with respect to the main effect of sampling time and station. The Shannon-Weaver species diversity index[10] was calculated for fish samples at each station. Scheffé's method of linear contrast[11] was used to determine significant differences in the mean length of dominant fish species among stations and sampling times.

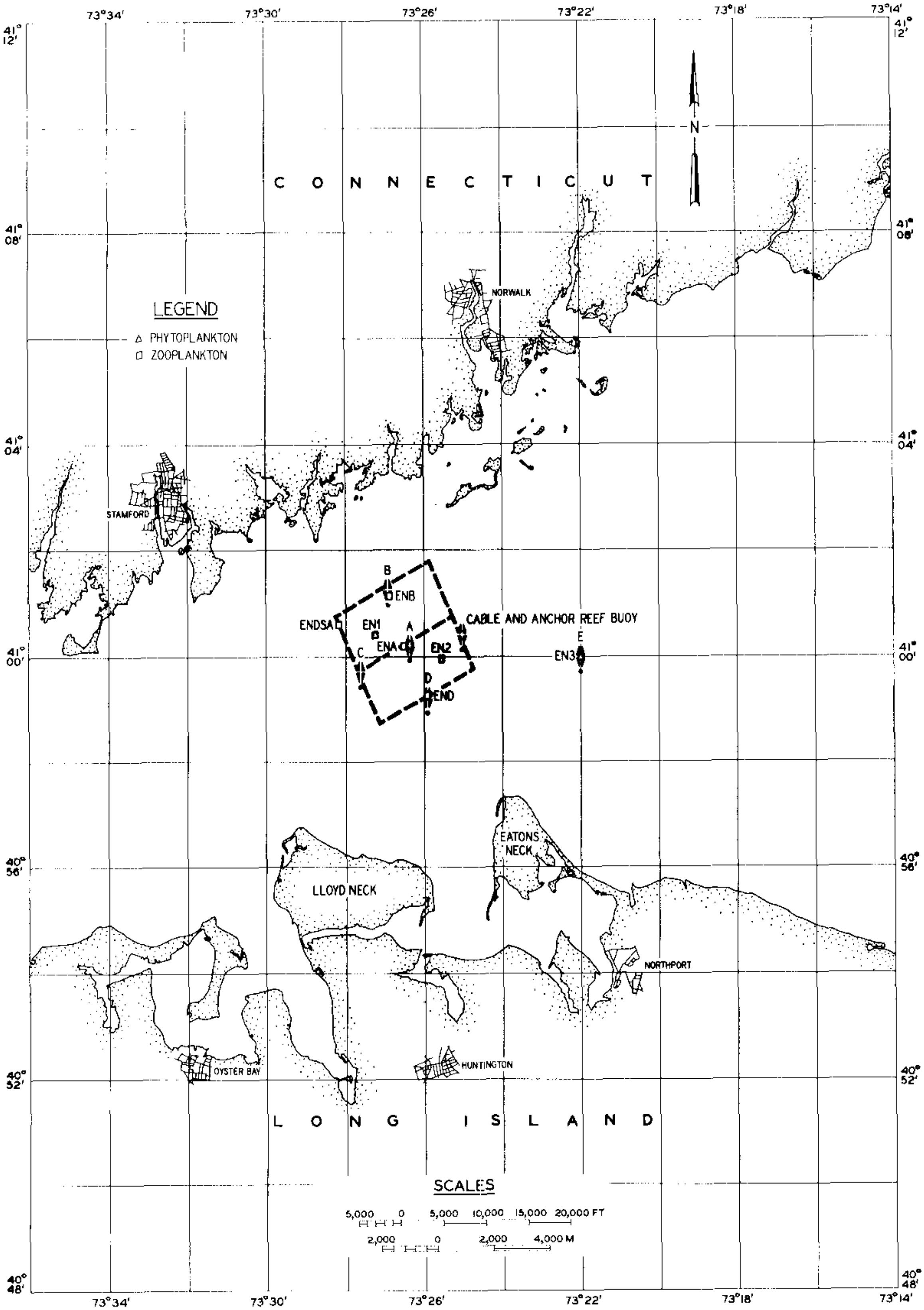


Figure 8. Locations of plankton sampling stations

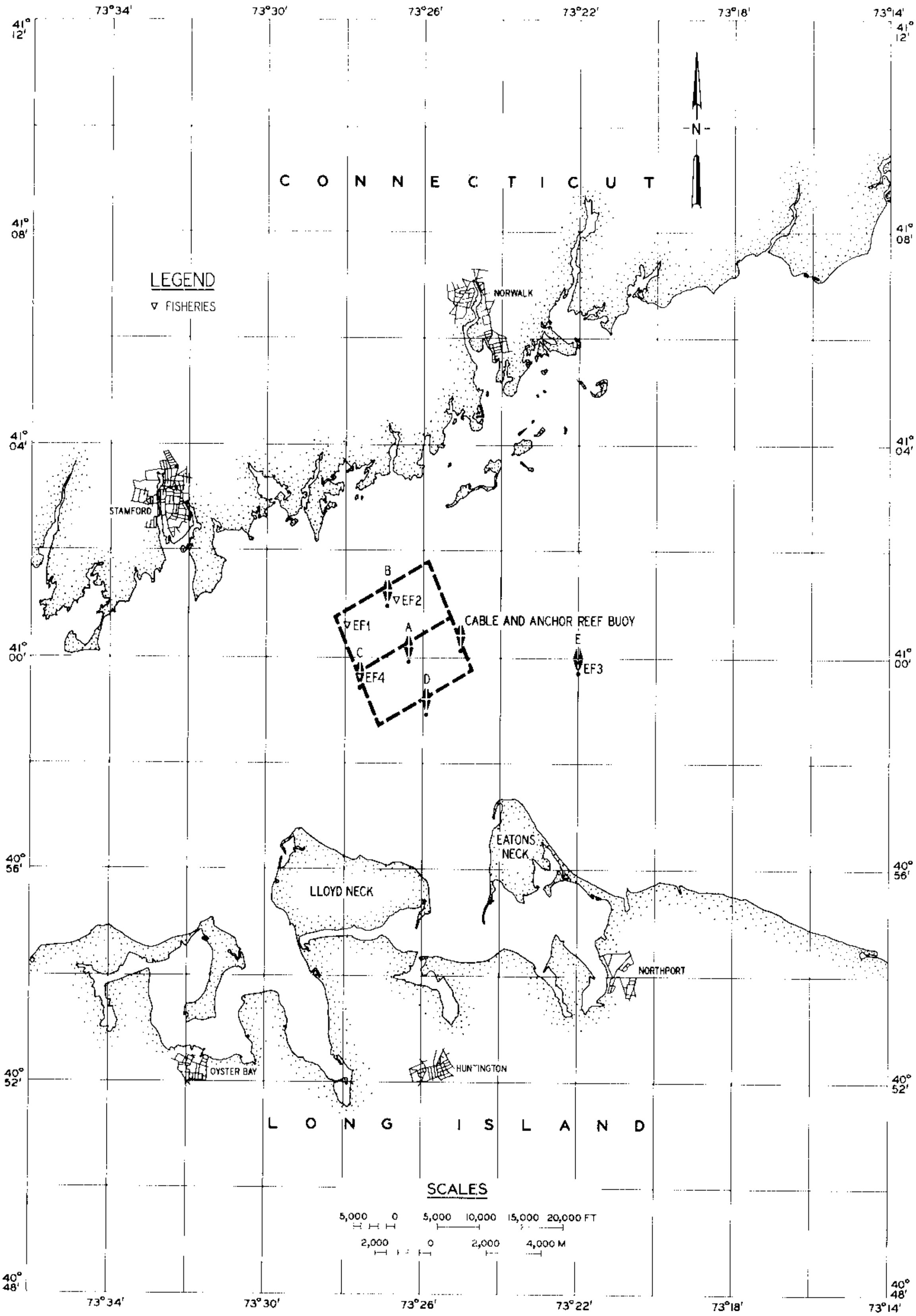


Figure 9. Fish sampling stations

Lobster heavy metal concentrations

41. A total of 20 lobsters, *Homarus americanus*, were collected from stations EF1 and EF3 on 2 June 1975 for analysis of silver, cadmium, chromium, copper, nickel, and lead concentrations in the tail muscle, gills, and digestive diverticulum. Tissues were dissolved in concentrated nitric acid, and metals were analyzed with an atomic absorption spectrophotometer. These analyses were conducted by the Middle Atlantic Coastal Fisheries Center, Milford, Connecticut.

PART IV: PHYSICAL STUDIES

Sediments

42. The Eatons Neck disposal site has predominantly silty sediments mixed with various amounts of sand in the central and western portions, with sand and gravel sediments occurring in the northern and eastern portions associated with Cable and Anchor Reef (Figure 10). Dredged material and other substances of anthropogenic origin are distributed over most of the site, based on reflectivity and rough microtopography defined by acoustic profiling, presence of artifacts (brick, cinder blocks, etc.) in sediment samples, and diver observations of sunken pilings and cables. Bottom irregularities were typically about 0.6 m, although some 5.5-m mounds were observed (Appendix A). It should be pointed out that the techniques used to identify dredged material were qualitative and subjective; consequently, the spatial distribution pattern presented for the material is generalized.

Bathymetry

43. Comparison between the 1974 bathymetry (Figure 11) and the 1961 and 1976 bathymetry (overlays 1 and 2, respectively, which are included in an envelope in the back cover of this report) may be used to indicate the general stability of the disposal area. Care must be taken when evaluating these contour maps because of the inherent problems associated with bathymetric surveying (vertical and horizontal controls) and contouring, especially in areas of rough microtopography like the disposal site.[12] Comparison of the 1961 and 1974 bathymetry surveys showed substantial accumulation within the disposal site, probably reflecting the reported disposal of 8.5 million m^3 of dredged material at Eatons Neck during this period. Evaluation of the 1974 and 1976 surveys indicated no appreciable bathymetric changes beyond the detection limits of the survey techniques. Dredged material disposal operations were terminated in 1974 prior to conducting the bathymetric

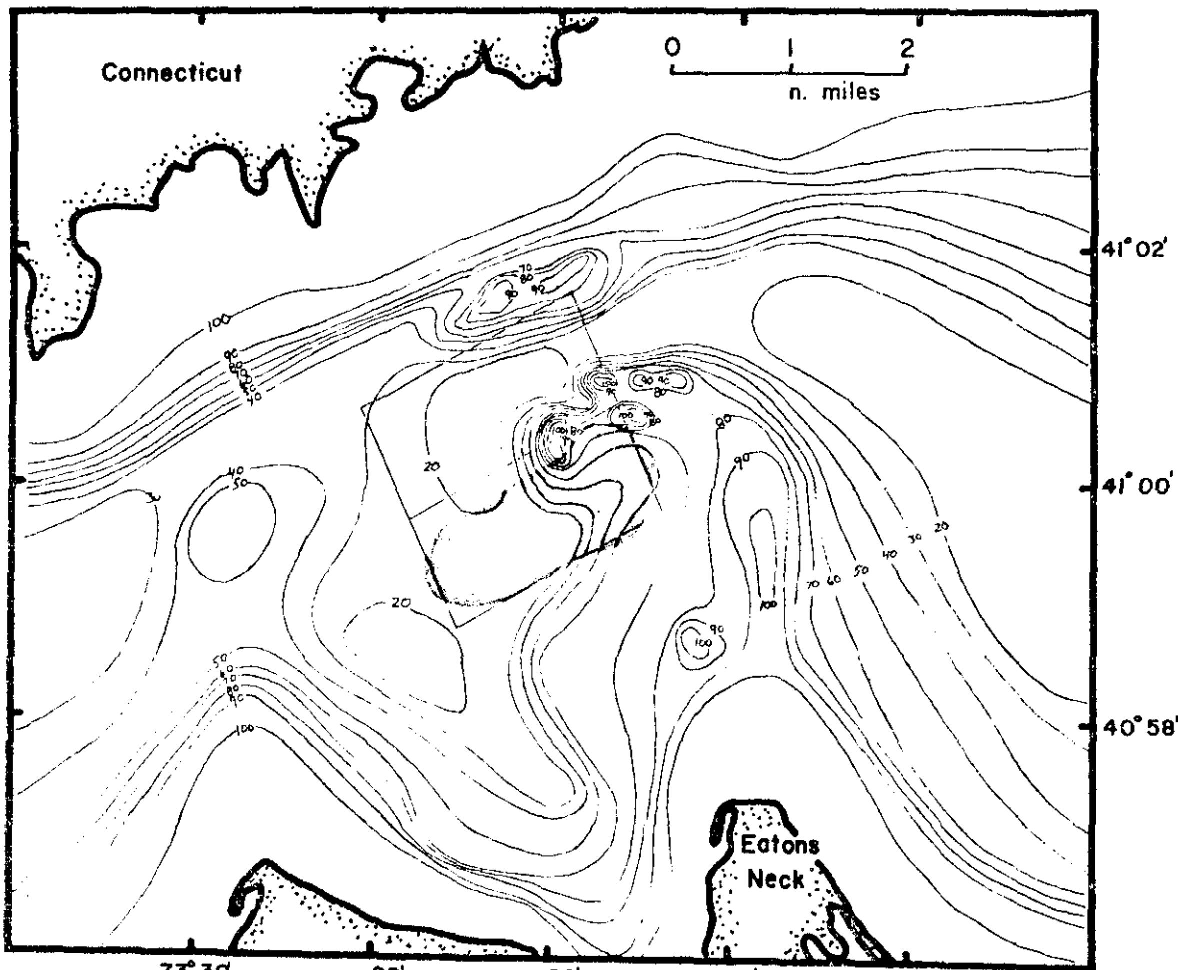


Figure 10. Distribution of sand at the disposal site and surrounding areas (10-percent contour intervals). The shaded area indicates portion of the bottom where extensive disposal has taken place. (Taken from Appendix A, Figure 8)

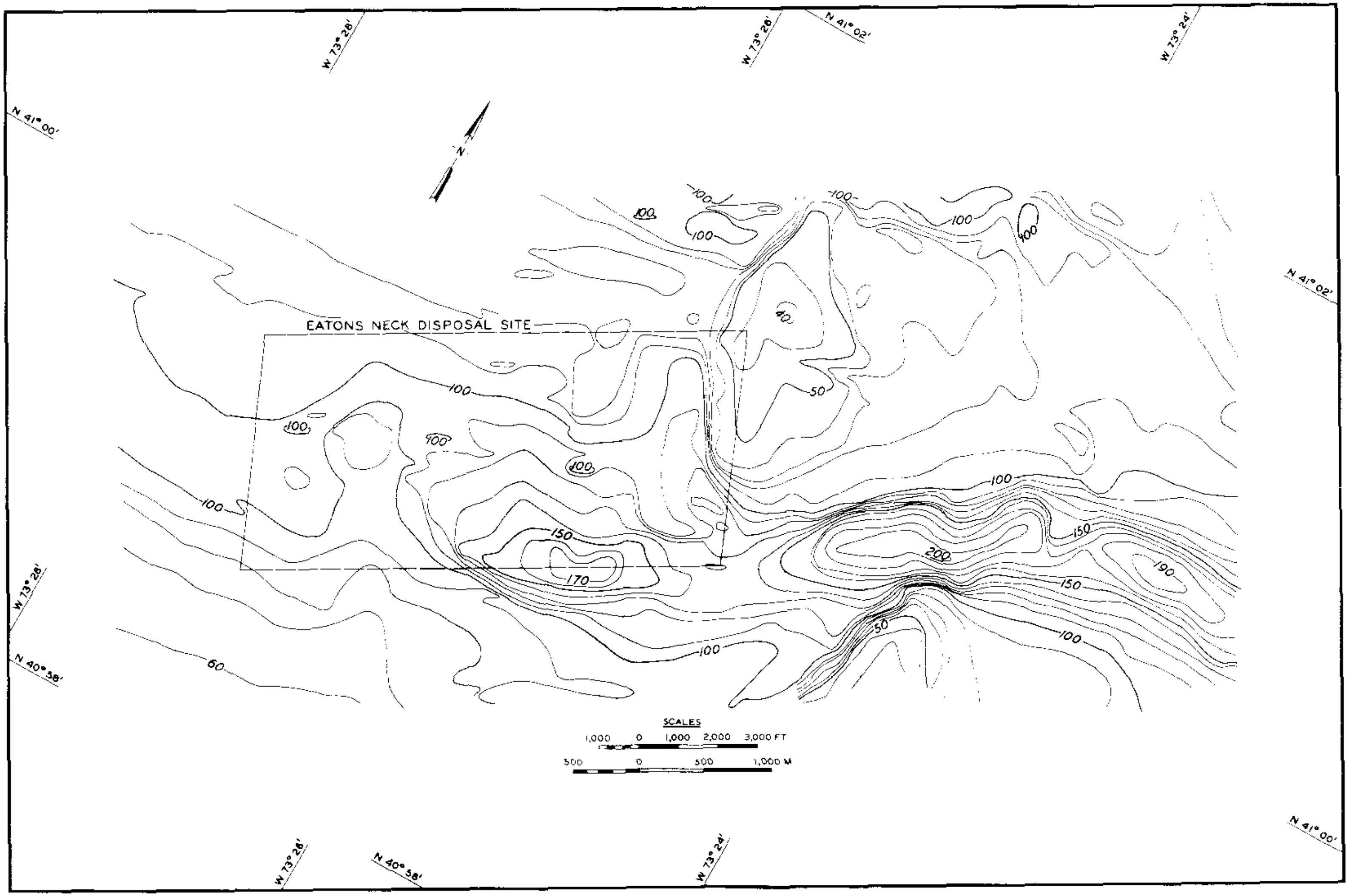


Figure 11. Bathymetry of the Eatons Neck disposal site based on a 1974 survey. Overlays showing results of 1961 and 1976 surveys are enclosed in an envelope in the back cover of this report.

survey. These data suggest that there was no substantial large-scale transport of deposited sediments from the Eatons Neck site during the time period of the investigations.

Currents and Circulation

Water-flow characteristics

44. Currents were found to flow predominantly, and usually with the greatest velocities, along the east-west axis of the sound, although low velocity currents were measured in all directions (Tables 2-10; Appendix A, Plates 19-30). This current pattern is believed to be a result of rotary tidal currents, much elongated along the semi-major axis. Periodograms computed from data collected at two current meter stations (EN-A and EN-C) indicate that the semi-diurnal M_2 (lunar) constituent is dominant with shallow water harmonics also exerting a significant influence on the tidal currents (Appendix A). Current velocities 2 m above the bottom were typically less than 30 cm/sec, but on rare occasion, velocities 50 cm/sec or greater were recorded (Table 2-10).

45. Progressive vector diagrams were used to summarize the gross water-flow characteristics. It should be remembered that these diagrams are based on Eulerian measurements (observations taken at a fixed point), but appear as Lagrangian-type flow paths. They should not be misinterpreted as representing the actual flow path of a parcel of water: they represent the net displacement of water averaged over successive ebb and flood tidal cycles for the observation period.

46. The progressive vector diagrams (Appendix A, Plates 1-18 and 31) illustrate the constancy of the net tidal cycle displacement vectors. In most instances, successive vectors appeared to be fairly uniform although variations with periods on the order of days were present. This is substantiated by the low-pass filter analysis of station EN-A (Appendix A, Figures 18 and 19). The variations are possibly large-scale current fluctuations caused by meteorological disturbances or the passage of eddies. No relationship was found between these

variations and wind or river runoff, although the frequency of occurrence of large variations was found to increase during stormy periods. Ideally a record length of several years would be required to accurately determine the average net displacement of bottom water.

47. The current vectors* represent average net near-bottom tidal cycle displacement for each observation period. However, the data are not synoptic (Appendix A, Table 3); seasonal or meteorological variations might also have influenced flow characteristics, for example. Synoptic stations were EN-1, EN-3, and EN-5 (9-20 September 1974), EN-6, a, b, c, d, and f (10-22 April 1975), EN-7, a, c, d, e, and f (30 April - 9 May 1975), and part of EN-A (31 October - 12 December 1974) and EN-C (31 October - 25 November 1974). Shoreward net flow was not observed at any of the stations. In most instances net flow was found to be toward the west or southwest at speeds less than 6 cm/sec. In two cases, EN-N (15 April - 29 May 1975) and EN-6d, southward net flows of less than 2 cm/sec were observed.

48. Cable and Anchor Reef, located northeast of the disposal area, is an obstacle to water flow and thus influences flow characteristics of the surrounding area. Following the basic principle of conservation of mass, diversion around this feature may result in increased current velocities adjacent to the reef as a consequence of the constructed flow, followed by decreased velocities downstream as the flow spreads out. Information obtained from synoptic stations EN-1, 3, and 5 are in agreement with this interpretation. Station EN-3, located adjacent to Cable and Anchor Reef, had the highest velocities and the greatest average net water displacement. Station EN-5, located approximately in the center of the original disposal area west of the reef, was found to have a much reduced net displacement. This, however, may be influenced by the increased water depth (32 m as compared to 26 m), which also has a compensating effect, or by the location of the stations relative to the main flow path.

---

* Note that the direction of the vector at station EN-6d was incorrectly plotted in Appendix A, Figure 14 as 255^{o} true north. The correct direction is 200^{o} true north as shown in Figure 12.

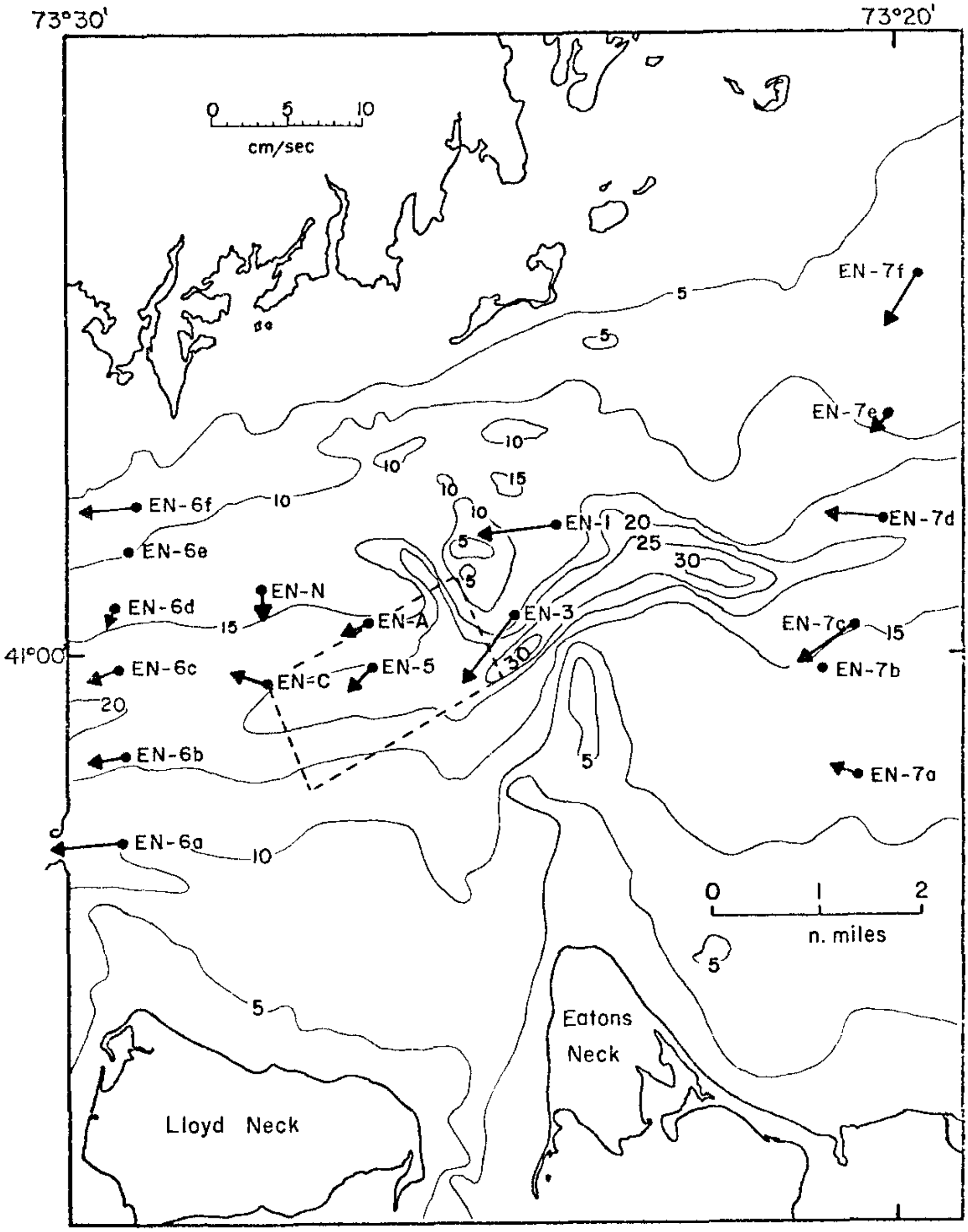


Figure 12. Net bottom current velocities recorded 2 m above bottom. (Taken from Appendix A, Figure 14)

49. The area behind Cable and Anchor Reef would be expected to have low velocities and water transport rates as a result of bathymetric shielding. During flood tide, flow interruption caused by the reef may result in a relative deficiency in the amount of water transported downstream behind the reef, while during ebb tide a buildup of water may occur. The reduced average net displacement found at station EN-A as compared with synoptic station EN-C may be a result of this bathymetric shielding. The horizontal extent of the bathymetric influence is not known, but it may have some influence on the flow as far away as station EN-6d, over 5 km west of the reef. The southward average net displacement at stations EN-N and EN-6d may be a consequence of this flow deficiency.

50. The reduced flow velocities associated with Cable and Anchor Reef may result in an environment favorable for the placement and retention of dredged material in portions of the site. Additional investigation is necessary, however, to define the extent of this area. The location directly behind Cable and Anchor Reef may be an erosional area due to the increased turbulence associated with the flow interference, with the area of reduced velocities being downstream from the reef.

Sediment transport

51. Although progressive vector diagrams are useful in illustrating net water-flow characteristics, they do not give any indication of sediment transport potential. An inherent problem of relating progressive vector diagrams to sediment transport is that the net transport of sediment may not necessarily correspond to the net transport or displacement of water. This difference may be a result of different physical properties governing sediment transport and fluid motion, i.e., shear stress and initiation of sediment-particle movement. This is especially true for bedload transport, but may not be as important for suspended load transport, since once suspended, the material will flow with the fluid.

52. Sediment transport is related to the velocity gradient of near-bottom currents, grain-size distribution, and sediment mass physical properties. Ideally, kinematics of fluid motion and shear

stress exerted on the bed (drag and inertial forces) should be determined for the area of interest. The current meter sampling mode used in this study documented overall circulation patterns and general hydraulic regime of the study area, but was not designed to measure near-bottom boundary flows necessary for shear stress calculations. This direct approach of evaluating the sediment transport potential at the Eatons Neck site was not undertaken because of the complexities involved in determining the necessary forces and the inherent problems of relating them to the transport of cohesive and heterogeneous material over a rough microtopography.

Wave and wind effects

53. From the wave data obtained at Cable and Anchor Reef during March 1975, little disturbance of the bottom at the disposal site by wind-generated waves is probable. Sufficient wave heights develop only during easterly winds of prolonged duration, since there is little effective fetch from any other quadrant. Generally, winter storm winds do not maintain a consistent direction long enough to develop wave height-to-length ratios large enough to generate significant orbital velocities at the bottom in water depths greater than 18 m. The principal effect of wind on the bottom at the disposal site is apparently to increase tidal stream turbulence, with effects due to wind-generated waves being less important (Appendix A).

Suspended sediment

54. An understanding of the processes and mechanisms involved in the distribution and rate of change of suspended sediment at the Eatons Neck site would require an elaborate sampling scheme and additional data. Yale University's 24-hr transmissometer station at EN-N was not sufficient to adequately describe temporal and spatial fluctuations or to substantiate sources of material that contribute to the concentration of suspended solids within the site. Wind and wave resuspension within the site or in adjacent shoal areas, tidal stream erosion, river runoff, and biological activity are all possible sources of suspended sediment to the water column.

55. Considering the previous discussion on waves, it is unlikely

that bottom wave orbital velocities capable of resuspending bottom material were generated at the site during this period. In addition, the data (Appendix A, Figures 25-27) indicate that the greatest increase in suspended sediment concentrations occurred during a period of minimum velocity at a slack tide stage. The fact that higher concentrations were first noted in the surface layers also casts doubt on the possibility of bottom resuspension during this time. Assuming a conservative value of 30 cm/sec for an average surface velocity during the first four hours of this observation period, the observed increase in suspended sediment concentration may be accounted for by advection from an area over 4 km away, possibly from a near-shore zone.

PART V: CHEMICAL STUDIES

Water Column Chemical Properties

Diurnal study

56. In October 1974 the tidal (diurnal) variability of several water column variables, including salinity, temperature, ammonia, nitrite, nitrate, dissolved phosphate, total phosphate, silicic acid, particulate nitrogen, particulate carbon, and chlorophyll *a* was determined. Samples were collected eight times over a 20-hr (1.5 tidal cycles) period at disposal site D (Appendix B, Figures B7-B20).

57. Salinity and temperature varied relatively little over the tidal cycle; both were lower at the surface and were constant with depth. Dissolved oxygen was uniform, although higher at the surface, an indication of photosynthetic activity. This was expected, but the data showed little decrease in surface dissolved oxygen concentration during the night, when respiration exceeds photosynthesis.

58. There were significant although different temporal variations in ammonia and nitrite, respectively, at disposal site D, both at the surface and at depth. In Appendix B this was attributed to the influence of eutrophic waters from Long Island Sound or from sewage-enriched harbors of Connecticut or Long Island.

59. Total phosphate showed greater variation than did dissolved phosphate. The data are questionable, because the dissolved phosphate concentration exceeded that of total phosphate in some cases.

60. Silica, particulate nitrogen, particulate carbon, and chlorophyll *a* at the surface showed temporal variations of different degrees. Table 12 gives a summary of the high and low values of each parameter. Any attempt at further interpretation is hampered by a lack of data. For instance, Figure B16, Appendix B, indicates that the 20-m peak for silica could have occurred anytime from 1620 to 2236 hours.

61. It is not entirely clear that data such as presented in Figures B9-B20, Appendix B, really identify "tidal variations" adequately for the parameters studied, because the lack of data points

causes the difficulty mentioned above. Secondly, tidal effects may not have been separated from nontidal effects such as sunlight intensity. This could be important for chlorophyll a, dissolved oxygen, particulate nitrogen, and particulate carbon. Nevertheless, Appendix B indicates there are significant temporal variations for several parameters.

Salinity during cruises Ace II-VII

62. *Temporal variation in salinity* (Appendix B, *Figures* B21-B26) represents the combined effects of tidal, seasonal, and spatial variability. It is stated in Appendix B that a comparison of these data with those taken in the diurnal study of October 1974 indicates most of the salinity variation is spatial rather than caused by tidal effects. The diurnal study was reported for one period at one station; hence such a generalization is not necessarily warranted. It appears that a seasonal variation in salinity exists. Salinity was high and uniform with respect to depth and location in December. Typical values were around 28.5 o/oo. Relatively low surface values at reference stations K and L were attributed to sewage and/or river flow. Salinities dropped to generally less than 28.0 o/oo in January and showed more variation with depth and location, especially in the eastern end of the study area. The lower values at reference stations G, M, and L were attributed to high flows of the Norwalk and Saugatuck rivers.

63. The drop continued in February, reaching typical values of 27.3 o/oo. Reference stations Z, V, U, and T showed some depth variation. By March, the typical value became 27.0 o/oo, with consistently lower surface values. The lowest values were present in May, when there were sizeable variations with both depth and location.

64. Pagenkopf and Bigham[13] gathered surface water-quality data from many sources, emphasizing 1970 to the present. They divided the study region into five polygons (Figure 13). The Eatons Neck disposal site lies slightly west of the boundary between polygons IV and V. Figure 14 shows a summary of their data for the mean monthly surface salinity, with a comparison to the flow of the Hudson River. A spatial gradient increased eastwards, and Pagenkopf and Bigham felt there was a definite inverse correlation between the Hudson River flow and the

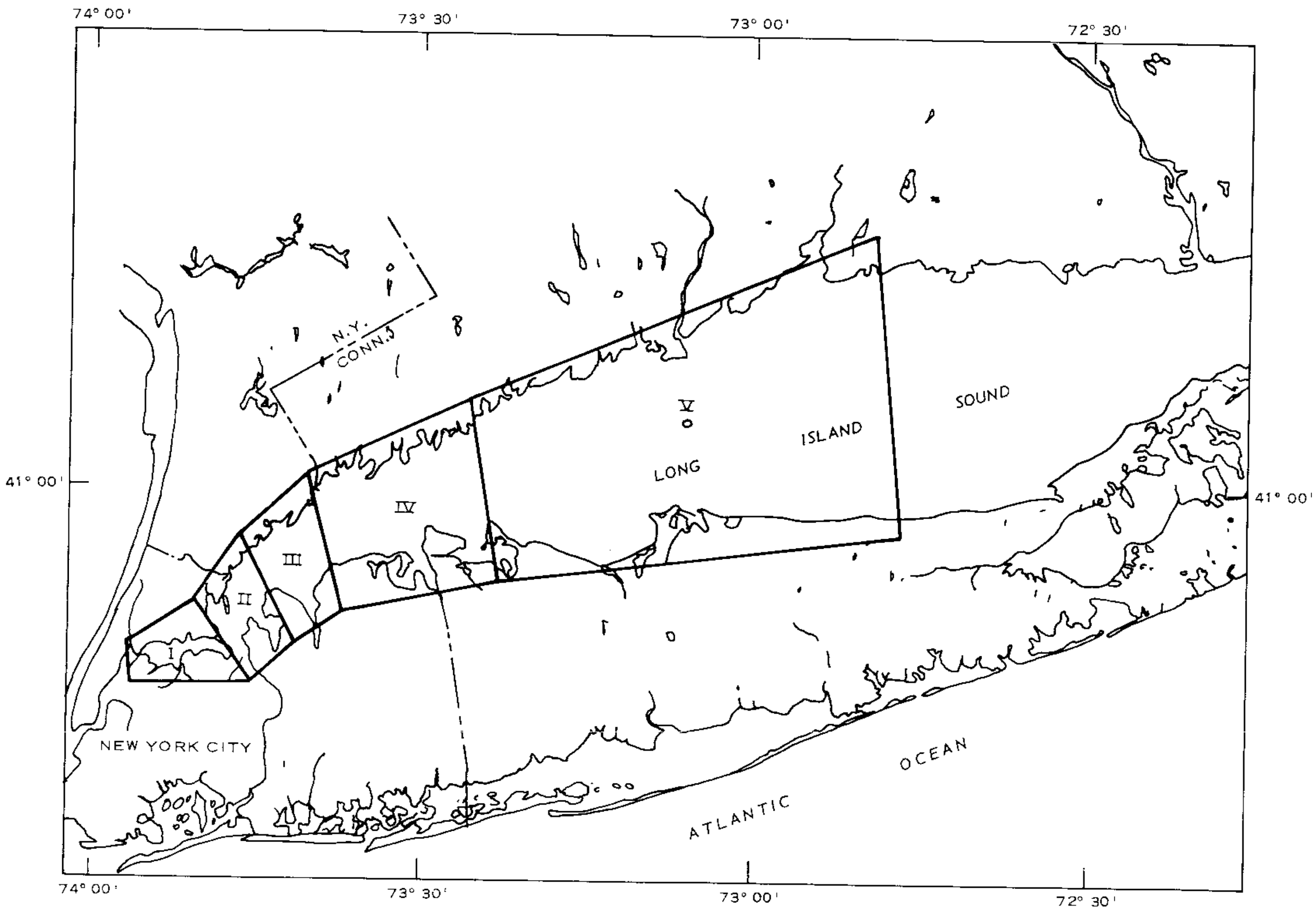


Figure 13. Divisions of Long Island Sound based on water chemistry attributes (from Reference 13)

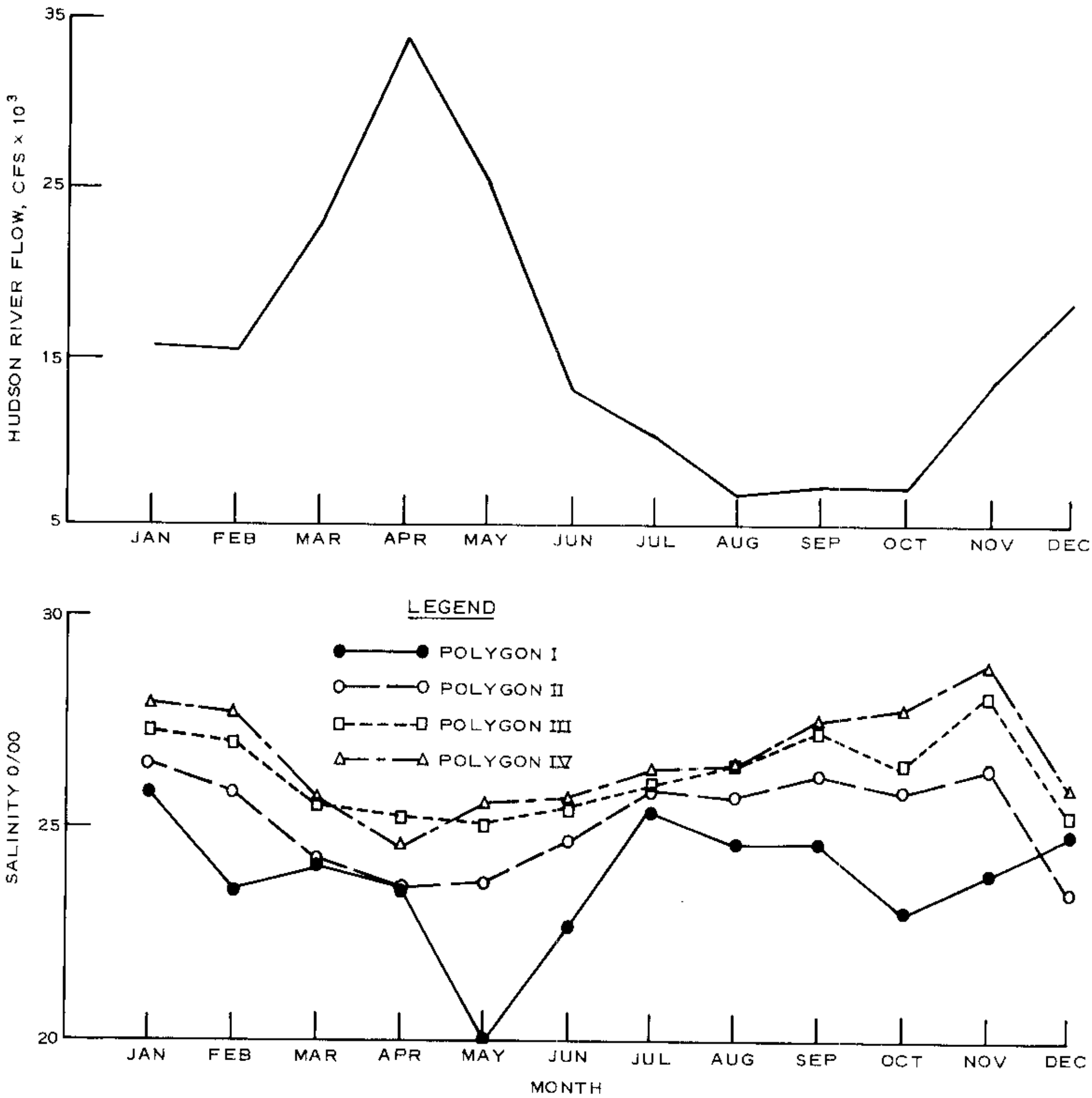


Figure 14. Mean monthly surface salinity (1969-1976) in polygons I to IV compared to Hudson River flow (1969-1974) (from Reference 13)

surface salinity in the Upper East River and western Long Island Sound. Their salinity values are generally lower (0.5 o/oo) than those recorded at Eatons Neck.

Horizontal and vertical distribution of water-column parameters

65. The distribution of water-column parameters is presented for three cruises (January, March, and May) by means of horizontal maps plus horizontal and transverse sections (Appendix B). The three cruises occurred during prebloom, bloom, and postbloom periods, as well as during high and low river flows. In addition, the seasonal cycle of spatially averaged results for each variable is given.

66. These plots and charts need to be interpreted with care. In all cases, data for the horizontal contour maps as well as for the longitudinal and transverse sections were taken over a 2 to 3-day period, but the data are plotted as though there were no temporal effects. Such an assumption was not always warranted because there does not seem to be adequate sorting of temporal versus spatial effects. Furthermore, there may not be enough data points to plot many of the horizontal contour maps, and a number of lines in the cross-section plots are of dubious validity. These reservations make it difficult to draw detailed conclusions.

Monthly sampling

67. Temperature and salinity. From October through March, the water was nearly isothermal. The coldest water ($2^{\circ}C$) was found in February. In April and May, the surface water temperatures had increased to about $8^{\circ}C$ and $15^{\circ}C$, and the bottom temperatures to $6^{\circ}C$ and $12^{\circ}C$, respectively. If hourly effects can be ignored, the data in Appendix B, Figure B28c and f, indicates a thermocline in May. This, combined with a possible halocline (Appendix B, Figure B30c and f), produced a stratified water column. Generally, surface salinities were lower near the Connecticut shore, possibly affected by the Norwalk and Saugatuck Rivers.

68. Percent dissolved oxygen saturation. Horizontal and vertical sections are given of the percent dissolved oxygen saturation in

Appendix B, Figure B33. The plots indicate that the water was nearly saturated in January (93-95 percent) and slightly supersaturated at all depths in March. During May, surface waters were highly supersaturated (>130 percent), but bottom waters were slightly undersaturated (80 to 95 percent). The authors of Appendix B attributed the higher supersaturation in the surface to photosynthetic activity and the undersaturation in the lower waters to the presence of a thermocline; however, the plot does not present hourly effects.

69. Pagenkopf and Bigham[13] described the annual variations of surface dissolved oxygen for polygons I-V (Figure 15). Polygon I, where the influence of the East River is greatest, had values consistently below saturation (e.g., 35 percent in August). Polygon II was also usually below saturation, except for March and April during the winter phytoplankton bloom. Polygons III and IV (Eatons Neck region) showed supersaturation at the surface from March to September. This area appears to be one of intense phytoplankton activity. Other values in the Eatons Neck area were close to saturation levels the year round in polygon V.

70. Ammonium. The diurnal study at dredge site D indicated an hourly effect, making the interpretation of the maps and sections for ammonia difficult. There seems to be an increase in concentration westwards during January (Appendix B, Figures B35 and B36). Surface concentrations ranged from 1 to 7 μM in the western end of the study area. Somewhat higher concentrations were also observed at stations closest to Huntington Bay.

71. The data taken in March were generally lower than in January, which was attributed to increased phytoplankton growth. By May, ammonia was nearly depleted in the surface waters (<1 μM). A slight increase westwards was found at 10 m, no significant north-south gradients, and a relatively uniform bottom concentration of 4 μM. These conclusions must be evaluated with Figure B11 of Appendix B in mind, which shows a sizeable hourly effect for ammonia.

72. The seasonal cycle for ammonia showed pronounced minima in December (1.2 μM) and March (1.0 μM). The authors of Appendix B

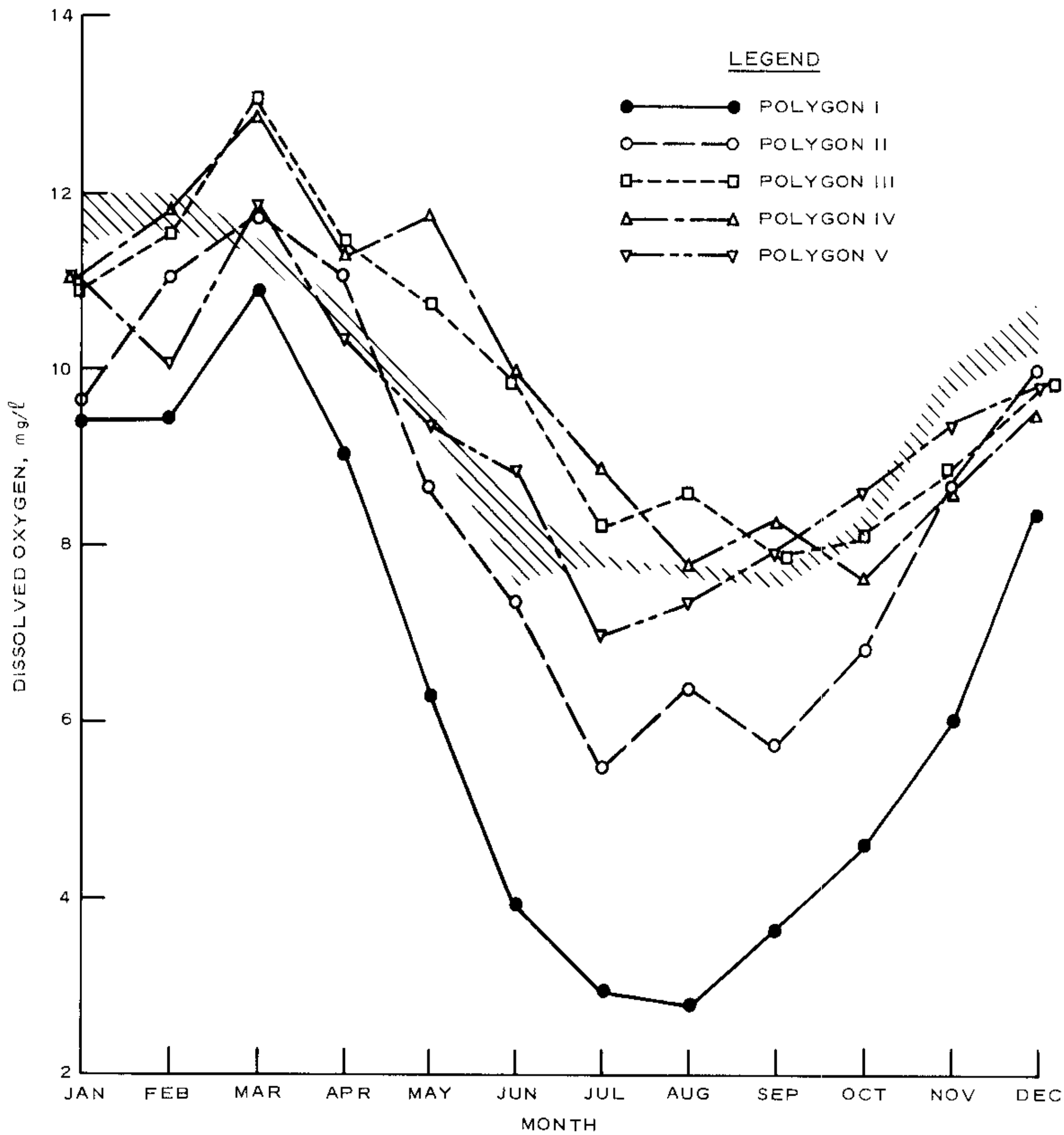


Figure 15. Mean monthly surface dissolved oxygen in polygons I to V (1969-1976) (from Reference 13)

attribute the March minimum to phytoplankton uptake, but did not offer any explanation for the December minimum. The increase in April and May was "probably due to zooplankton excretion or regeneration processes, or a combination of both" (Appendix B).

73. Surface ammonia levels were plotted by Pagenkopf and Bigham[13] (Figure 16). They also found a spatial gradient and fall and winter values higher by a factor of 2 compared to spring when phytoplankton activity was greatest. They felt the gradient indicates that the New York City municipal waste treatment plant is the controlling source for sewage-related pollutants in this area.

74. Nitrate. During the January-May sampling period, nitrate concentrations ranged between 18 μM and less than 1 μM. A small gradient decreasing eastward was present during January; a more pronounced gradient increasing eastward at the surface occurred in March, with surface values ranging from 6 μM in the western end to 13 μM at the eastern end of the study area. Concentrations increased with depth at most stations. The lowest values for nitrate occurred in May (0.5 to 5 μM) when there was no east-west gradient at the surface, but there seemed to be one at 10 m, increasing eastward. A mean maximum of 17 μM for nitrate was observed in February. Riley[2] observed maximum nitrate concentrations of 16 μM in 1954-1955.

75. Other workers[13] have summarized surface nitrate data for western Long Island Sound (Figure 17). Values ranged from 0.2 to 20 μM, with highest values in polygon I. The concentration generally decreased away from the East River (decreasing eastwards), which is opposite to that reported in Appendix B for March. Pagenkopf and Bigham noted that the lowest surface nitrate values occurred from March to August, whereas the lowest ammonia values were present from January to June.[13] Thus it appeared to them that the winter phytoplankton may use ammonia at a faster rate than nitrate, until the ammonia is depleted to the point where nitrate consumption must increase.

76. Dissolved phosphate. As indicated earlier, the dissolved and total phosphate data are questionable, since in some cases dissolved phosphate values exceeded those for total phosphate.

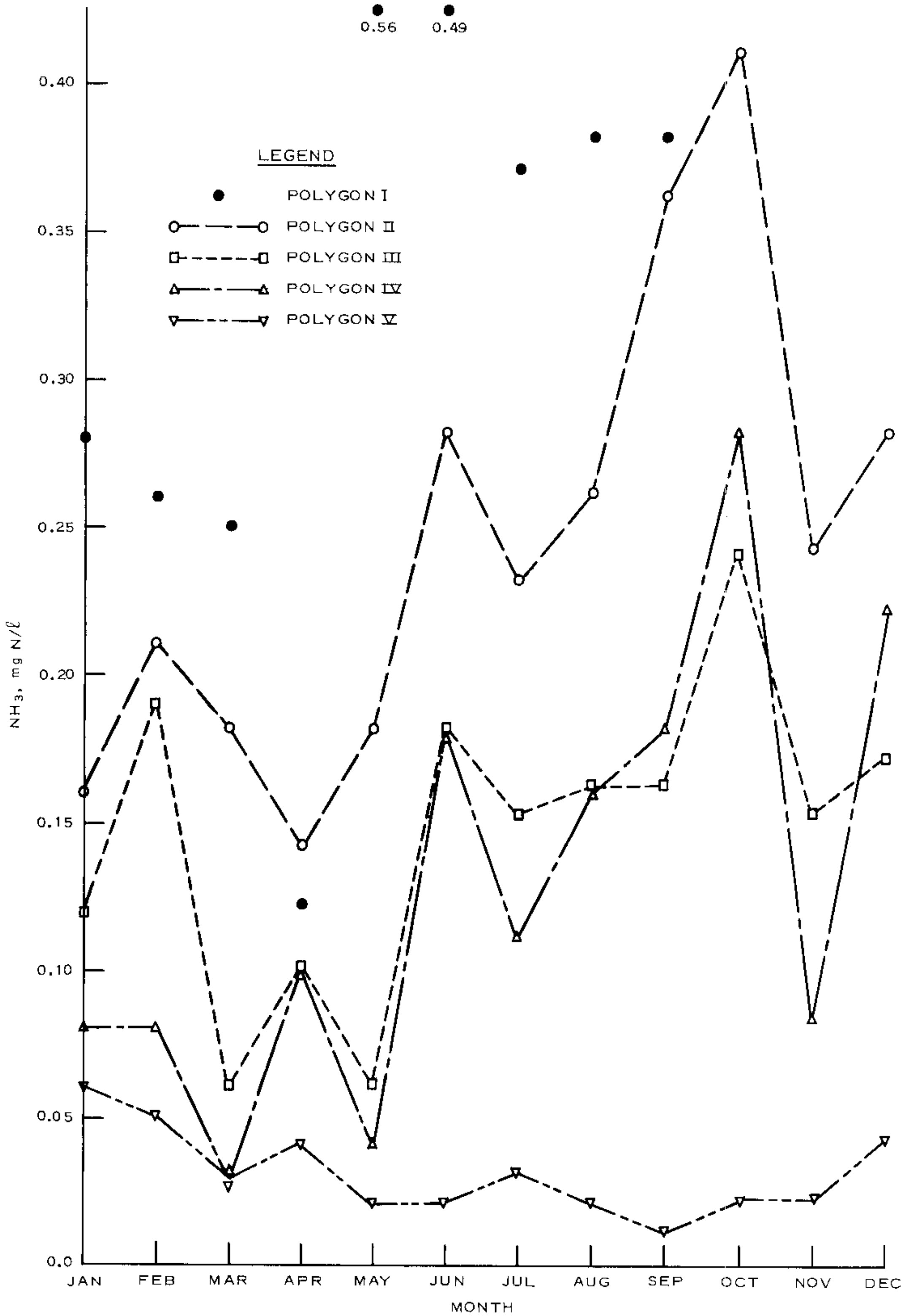


Figure 16. Mean monthly surface ammonia in polygons I to V (1970-1976)
(from Reference 13)

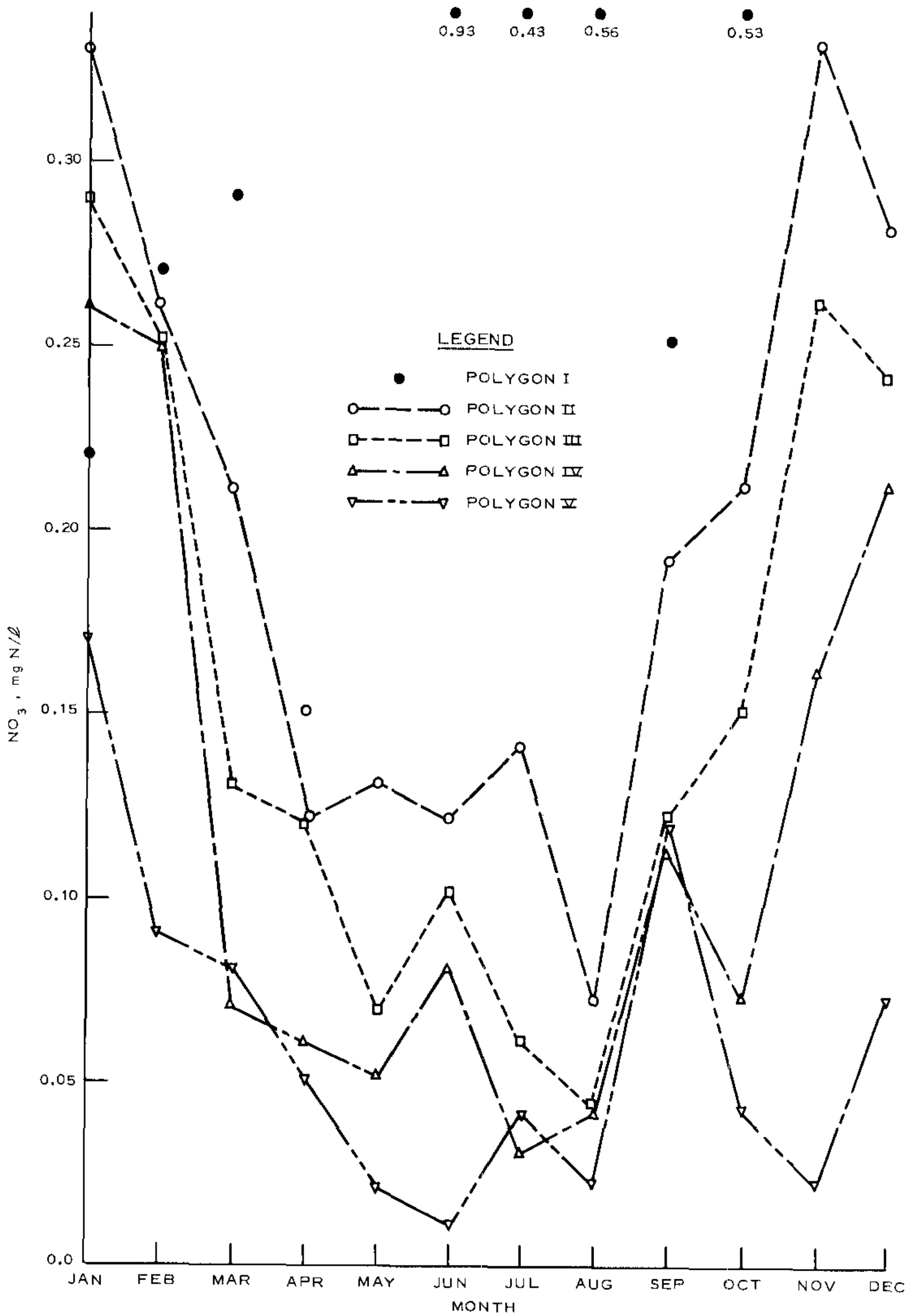


Figure 17. Mean monthly surface nitrate in polygons I to V (1970-1976) (from Reference 13)

77. In January, vertical concentrations of dissolved phosphate were nearly uniform at slightly over 3 μM. There appeared to be a slight increase southward towards the Long Island shore. In March, values were reduced to a range of 1.6 to 2.2 μM. There seemed to be concentration gradients increasing towards the north and east in the deeper waters. By May, dissolved phosphate concentrations had decreased to a range of 0.4 to 1.6 μM. Seasonal mean values for dissolved phosphate at Eatons Neck are similar to but are consistently 1 μM higher than data reported by Riley.[2]

78. Figure 18 indicates a year-round gradient, decreasing eastwards across polygons I-III, for surface phosphate. Values ranged from 0.3 to 3 μM, in rough agreement with the Eatons Neck data. Pagenkopf and Bigham[13] found summer and winter variations pronounced, indicating biological uptake during the winter and spring blooms. They noted that their data indicated ammonia was fairly constant seasonally in polygon V, whereas the phosphate concentrations were highly seasonally dependent. They felt that this was due to local transport mechanisms rather than biological activity.

79. Selica (silicic acid). In January, the silica concentrations were nearly uniform at 28 μM with depth. Concentration gradients increasing toward the west and north shore of Long Island were observed. By March, the concentrations had decreased to 10 to 20 μM, with the higher concentrations at depth. Gradients increasing towards the west and north were observed during this period. Silica concentrations had decreased to 2-12 μM by May, again with an increase at depth. There were neither east-west nor north-south gradients at this time. At Eatons Neck a strong seasonal variation in silica was indicated with the decreased levels in surface waters in April and May probably due to phytoplankton uptake.

80. Particulate carbon. In January, the distribution of particulate carbon was nearly uniform at about 200 μg/ℓ. In March, average concentrations were in the range of 800 μg/ℓ. At this time, the highest concentrations were found in the western portion of the study area near the north shore of Long Island. Concentration decreased with

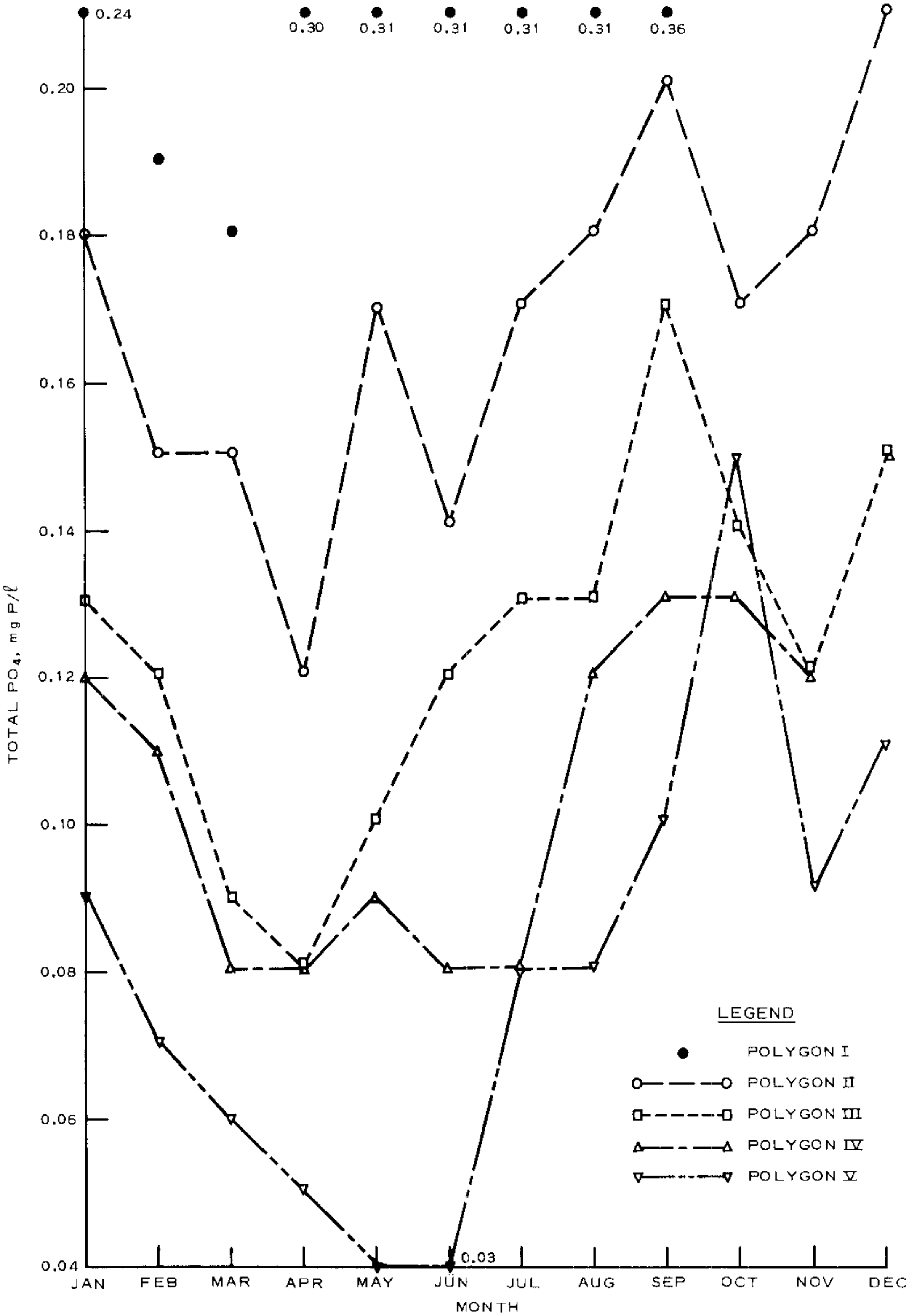


Figure 18. Mean monthly surface phosphate in polygons I to V (1969-1976) (from Reference 13)

depth at most stations. In May, concentrations were more patchy, ranging from 600 to 2000 μg/ℓ. Again there was a general decrease with depth. In Appendix B it was suggested that mean particulate carbon values observed in March, April, and May were influenced by increased biological production. However, Appendix B, Figure B50, indicates that the "all values" average in March was lower than the surface or bottom values.

81. Particulate nitrogen. The distribution of particulate nitrogen at Eatons Neck was found to be similar to that of particulate carbon. Lowest values were found in January (40 μg/ℓ), when the spatial distribution was nearly uniform, with a slight increase toward the western end of the study area. In March, the values were in the range of 100 μg/ℓ, and there were strong concentration gradients increasing towards the west (less than 80 μg/ℓ in the east to 140 μg/ℓ in the west). At many stations, the concentration decreased with depth. The highest particulate nitrogen concentrations were observed in May (80 to 240 μg/ℓ) patchy distribution pattern.

82. Chlorophyll a. Along with particulate carbon and particulate nitrogen, chlorophyll a was uniformly low in January (around 2 mg/m^3). By March, levels had increased to 10 to 24 mg/m^3, with the higher concentrations near the north shore of Long Island at the western end of the study area. Concentrations decreased with depth at all stations at this time. However, the Eatons Neck data indicated that the greatest concentration for March was at the bottom. During May, levels occasionally exceed 20 mg/m^3 and the distribution was patchy. The higher concentrations seemed to be at the shoreward stations on both sides of the Sound. Levels seemed to increase towards the west and decrease with depth at most stations.

83. Pagenkopf and Bigham[13] plotted seasonal variations of chlorophyll a, phosphate, and nitrogen (ammonia plus nitrate) (Figure 19). The figure indicates winter and spring blooms, with a weaker bloom in August. Nitrogen concentrations in polygons II, III, and IV seemed to be directly correlated with the phytoplankton blooms. Phosphate data revealed a similar correlation, except that phosphate tended to be more

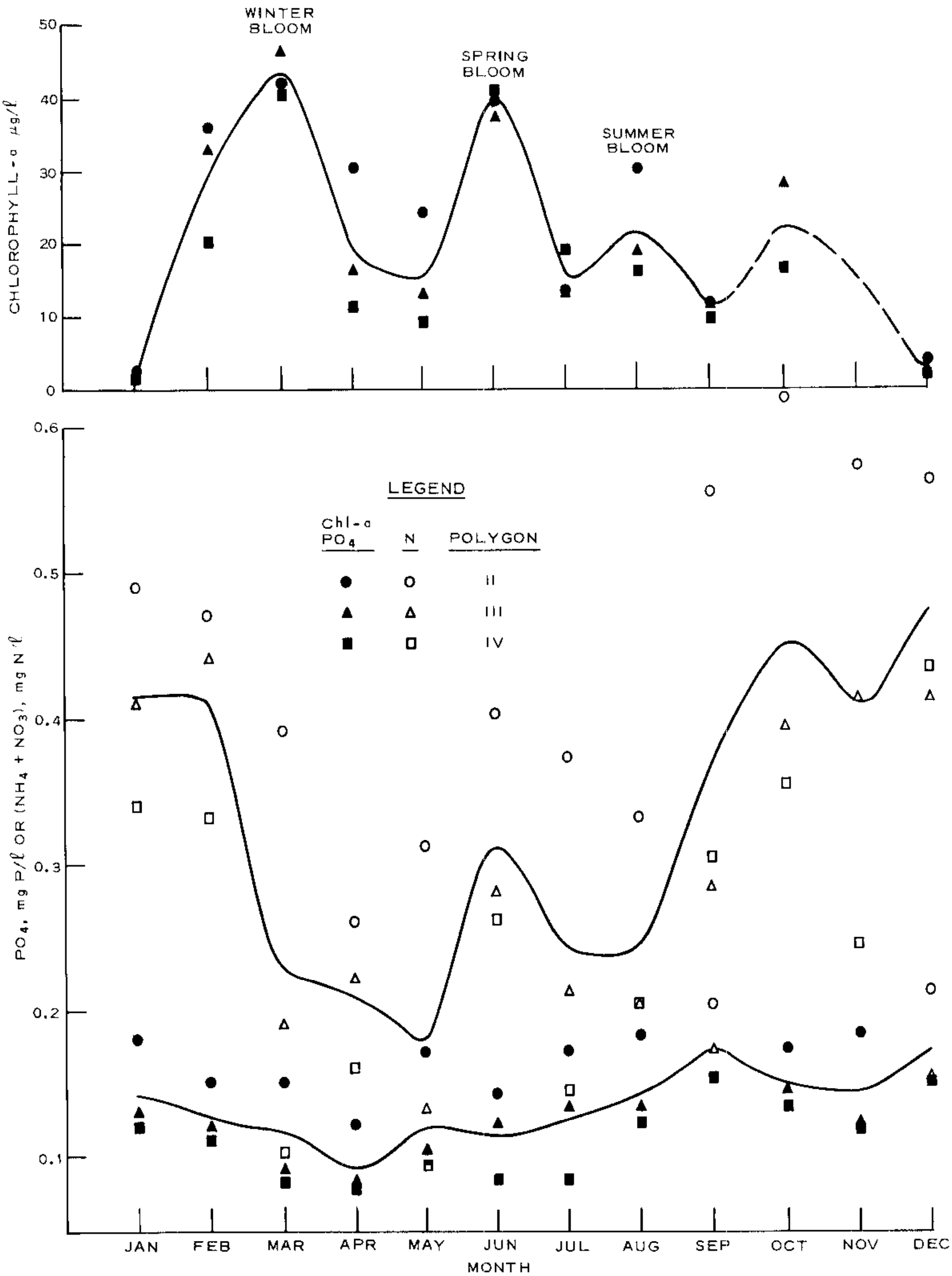


Figure 19. Comparison of chlorophyll a to phosphate and total nitrogen averaged over polygons II-IV (from Reference 13)

biologically conservative and temperature independent. According to these authors, one reason for this is that the uptake rate by phytoplankton of phosphorus is about 15 times less than that of nitrogen. Phosphate and nitrate concentrations decreased eastwards. Chlorophyll a concentrations, on the other hand, increased eastwards through polygon III, and from there decreased farther towards the east. Hardy and Weyl[14] observed the same phenomenon and concluded that the maximum level of chlorophyll a was not entirely correlated to nutrient levels, but might also be affected by other factors such as toxic materials or turbidity.

84. Suspended solids. During January, suspended solids concentrations were fairly uniform with surface values of 2 to 4 mg/ℓ and bottom values of about 5 mg/ℓ. A concentration gradient increasing westwards was observed at the surface and 10-m depth. The distribution in March was similar. Slightly higher surface concentrations were found on the north side of the sampling area. In May, somewhat the same pattern was found; however, bottom concentrations were considerably higher (7 mg/ℓ), especially at the western end of the region.

85. In October, December, February, and March, the particles at selected stations ranged from 0.8 to 12 μm, with the highest frequency at 1-2 μm (Appendix B, Figure B60). Unfortunately, the stations were not identified nor were the sampling depths indicated.

86. Dissolved metals. The distribution of dissolved metal concentrations showed very little temporal or spatial variation greater than the analytical error (Appendix B, Table B1).

87. Lead and cadmium were the only metals whose concentrations at the western end of the Eatons Neck study area were slightly higher than at the eastern end. The seasonal cycle of mean concentrations are given in Appendix B, Figure B62, which does not indicate depths.

88. Dissolved cadmium, iron, lead, and manganese apparently increased during the December-January interval, whereas copper and zinc perhaps decreased. All except iron seem to have decreased in the February-March interval. With the exception of dissolved zinc, all metals (copper, cadmium, iron, and lead) either remained constant or increased from March to the end of the sampling period.

89. The cadmium, copper, and lead concentrations were about twice those reported by Dehlinger et al.[15] for the eastern sound during August 1972 and February 1973. The increased lead and cadmium concentrations may have been due to anthropogenic inputs to the East River and contaminated aerosols (Appendix B). Mytelka et al.[16] and Chen et al.[17] have shown that effluent from sewage plants on the East River is a major source for dissolved metals such as lead and cadmium. Klein et al.[18] reported concentrations of dissolved lead and cadmium to be 530 μg/ℓ and 3 μg/ℓ, respectively, for the lower East River.

90. Suspended metals. The concentrations of suspended silver, cadmium, chromium, copper, iron, manganese, lead, and zinc were determined (Appendix B, Table B8). Appendix B, Figure B63, includes vertical sections for the January cruise. The figure shows no significant vertical or horizontal gradients. The seasonal cycle of suspended metal concentrations is included in Figure B64, but there is no depth identification. The relatively higher concentrations of iron and manganese were said to be probably due to oxide particulates.

91. All particulate metal concentrations except cadmium showed some increase in the February-March interval, a tendency to level off or actually decrease in the March-April interval, and an increase in the April-May period. Cadmium seemed to show an increase during March-April and a decrease during April-May.

Sediment Geochemistry

Description and classification

92. The sediments were mainly light-grey to black clayey silts. The black color was invariably associated with the odor of hydrogen sulfide, and many sediments were covered by a thin layer of black, organic-rich material.

93. Sediments at the reference site (station A) were sandy and became increasingly fine grained to the east. To the west of the reference site, the bottom mud graded to sandier sediments, with significant gravel at stations B', C, EB8, and EB4. To the west of stations

D and EB4 in the disposal area, the sediments were generally sandy. This latter gradation can be attributed to shallower depths and/or the possible effects of bottom currents. Sizeable variations occurred in grain-size data at a number of stations; this probably reflects navigational error and general patchiness associated with the irregular topography in the study area.

94. Table 13 includes the sediment texture data taken at reference station A at three different times (4 November 1974, 5 Janaury 1975, and 22 April 1975). The data suggest that with the possible exception of the silt and clay fractions on 5 January 1975, there was little change in sediment texture at station A with time. The texture of the sediment at reference station A is compared to that at the disposal site for Core III (22 May 1975) in Table 14. Data from cores DSA-1, DSA-2, DSA-3, DSA-4, DSA-B, and DSA-C were averaged to obtain disposal site averages. The relative amount of gravel is about the same at the two sites; sand at the reference station is higher, but the relative amount of silt is lower; the relative amount of clay is about the same at the two locations except for the top layer.

pH

95. Table 15 presents a summary of the ranges of pH found in the water column and sediments during the study period. Both regions had slightly alkaline values; however, the pH range of the sediment was generally lower than that of the water. There did not appear to be large seasonal changes. The sediment pH at reference station A is compared to disposal site DSA in Table 16. The pH appears to be slightly more acidic at station A for all depths.

Mineralogy

96. The top 10-cm sections of 10 selected cores were analyzed for bulk mineralogy by X-ray diffraction; samples were found to be composed principally of quartz and feldspar, with only minor amounts of amphiboles and clay. Microscopic analyses of bottom sediments from western Long Island Sound reported by McCrone[19] included, in addition, aragonite, calcite, muscovite, biotite, kyanite, dolomite, garnet, magnetite, hematite, and zircon. The clay fraction was mainly chlorite

(iron-rich type), illite, kaolinite, and mixed-layer montmorillonite with traces of quartz, orthoclase, and plagioclase.

97. Quantitative estimates of clay mineralogical composition did not reveal any significant trends from one station to another. Subsurface samples from reference stations A and F and disposal site D were also analyzed. The clay mineralogy was found to be uniform from top to bottom, implying no structural transformations during early diagenesis.

Particulate nitrogen and carbon

98. The nitrogenous component of organic matter in the sediments ranged from 0.01 to 0.46 percent by dry weight. At many stations there was a general decrease with depth. The carbon/nitrogen ratios ranged from 5 to 12, which is similar to that reported for the New York Bight.[20, 21]

99. Kaplan[22] found that the total nitrogen in the sediments ranged from 0.01 to 0.17 percent, the maxima occurring between 0.3 and 0.6 m below the sediment/water interface with no apparent relation to total organic or mineral content, grain size, pH, and Eh. However, Kaplan took grab samples for analysis.

100. Particulate carbon in the sediment surface and subsurface samples varied from 0.32 to 0.46 percent by dry weight. No calcite or aragonite was found. In general, the surface samples were markedly enriched compared to the subsurface, with a general decrease in particulate carbon with increasing depth. There appears to be slightly less total organic carbon (TOC) at the reference station compared to the dredge site (Table 17). The same trend was noted for total organic nitrogen (TON) in the sediments (Table 18).

Oil and grease

101. Hydrocarbon extracts from sediments were found to range from 0.01 to 0.44 percent by dry weight in the sediment samples. The concentration profiles of Figures B82-B90 of Appendix B indicate enrichment in the upper layers. No significant relation was found between hydrocarbon content and mineralogy of the cores. The authors felt that some of the large variations found in the surface samples may have been due to differences in particle-size distribution. McCrone[19] found

that the organic content was greatest in the topmost sediment. In his data, oil and grease content decreased within the top 0.3 m, below which it was fairly uniform. The oil and grease contents of reference station A and the disposal site DSA are shown in Table 19. It is difficult to make comparisons, since the data show considerable variation. There seems to be no major differences between the two locations except perhaps at the 30- to 50-cm interval.

Cation exchange capacity

102. The cation exchange capacity (CEC) of surface and subsurface samples varied from 0.0 to 99.6 meq/100 g of dried sediment. For several cores, there is a general trend of decreasing CEC with increasing depth. This pattern probably cannot be attributed to grain-size distribution or fine-fraction mineralogy. The CEC seemed to vary with values for exchangeable calcium.

103. McCrone[23] found CEC values in the range of 30 to 40 meq/100 g for surface sediments in the Hudson River Estuary. He felt that clay-sized organic matter, rather than clay minerals, accounted for the largest fraction of the CEC.

104. There seems to be little difference in the sediment CEC between the reference and disposal sites; values at reference station A generally fall within the range of those at the disposal site (Table 20). If anything, the values at reference station A may be lower.

Total and dissolved metals

105. Sediments. The metal concentrations in the sediments showed large variations from one station to another. The ranges of concentration in sediments were: copper (Cu), 6-230 mg/ℓ; lead (Pb), 4-145 mg/ℓ; zinc (Zn), 19-278 mg/ℓ; cadmium (Cd), 300-3100 mg/ℓ; mercury (Hg), 5-1420 mg/ℓ; nickel (Ni), 6-33 mg/ℓ; manganese (Mn), 124-1628 mg/ℓ; and iron (Fe), 7,000-38,000 mg/ℓ.

106. The phrase "in sediments" apparently is intended to mean bulk sample analysis, as indicated in paragraph 76, page 34, of Appendix B. If this is true, the above values include particulate and dissolved metals. The drying temperature of the bulk samples was not specified.

107. In most cases, the highest concentrations of copper, lead, zinc, cadmium, and mercury occurred near the surface. Iron, manganese, and nickel showed more erratic patterns. The total metal and interstitial metal concentration-depth profiles for the cores collected are given in Figures B91-B125 of Appendix B. A comparison of total sediment metal concentrations in the 0- to 10-cm layer is made in Table 21. There seems to be no significant differences between the reference station A and disposal site DSA.

108. Interstitial water. The concentrations of dissolved metals in the pore waters were generally greater than those in the overlying water column. This is in agreement with observations of several other workers, including Presley et al.,[24] Brooks et al.,[25] and Duchart et al.[26] The dissolved metals concentrations showed a wide range of variation: Cu, 1.6-92.2 μg/ℓ; Pb, 0.9-32.2 μg/ℓ; Zn, 2-269 μg/ℓ; Cd, 0.03-2.68 μg/ℓ; Ni, 0.3-15.5 μg/ℓ; Mn, 80-11250 μg/ℓ; and Fe, 11-968 μg/ℓ.

109. At a few stations, some metals showed a correlation with depth, but most exhibited an irregular variation. Interstitial concentrations of some of the metals are compared in Table 22. There seems to be little difference between the reference station A and the disposal site DSA.

110. Since the mineralogical and grain-size distribution did not show any trend with depth, these parameters cannot account for the metal concentration profiles. Turekian[27] observed a similar distribution in a core from central Long Island Sound and argued that in reducing sediments, the concentration of sulfide ions in sediment pore waters determines the mobility of metals. The authors of Appendix B presented in Table B9 "expected equilibrium concentrations for some metals in pore waters of sediments having a sulfide ion activity of 10^{-9} moles/litre at $25^{o}C$." Some of the values are interesting. For example, the expected equilibrium concentration for mercury is $10^{-43.7}$ moles/litre. This is equivalent to around 10^{-20} atoms of mercury per litre, or 10^{20} litres per atom. That presumably means one atom of mercury in a volume about one-third the size of the Atlantic Ocean. This is to say that the interpretation of very small solubility products must be done with

circumspection, especially since no sulfide data were included in Appendix B. The role of hydrated oxide precipitation and sorbtion could also be important, and so the fact that they do not precipitate as sulfides does not necessarily mean that the metals are mobile within the interstitial water.

111. At Eatons Neck the concentration levels of copper, zinc, cadmium, lead, and nickel are much higher than those expected from control by precipitation of their sulfides, and in Appendix B this was attributed to the presence of organic complexes or other precipitation-dissolution reactions. In Appendix B, it was concluded that probably these metals were associated with the humic-acid fraction or with the oil and grease component. This conclusion was based on the observation that the upper sediment layers have relatively higher carbon content than deeper sections. Iron and manganese were thought to be present as sulfides because the observed interstitial concentrations were below the solubility of their sulfide phases and because the black color of many hydrogen sulfide-smelling sulfides is indicative of the present of iron sulfide.

112. In the opinion of WES, the above rationale is ambiguous. Before one can say whether or not the concentration of a metal is governed by precipitation of a particular solid phase, one has to know some details about the nature of the dissolved metal species, and relating an observed dissolved concentration to a thermodynamic constant should not be done without a knowledge of the dissolved speciation. In addition, before one can actually use a thermodynamic constant to interpret dissolved concentrations, one must know the activity of the solid phase. Finally, iron sulfide is not necessarily black, nor is it the only possible black sulfide, even though it is common.

113. At Eatons Neck it was found that lead, copper, zinc, mercury, and cadmium were being introduced to the sediments anthropogenically at rates much faster than natural ones, while iron, manganese, and nickel had deposition rates much greater than man-induced fluxes. The total metal content of the sediments was not associated with the clay fraction, implying to the authors of Appendix B that the metals were not

bound to surfaces and edges of the fine-grained component. Nickel, however, showed a covariant relationship with clay content.

Interstitial nutrient concentrations

114. Interstitial ammonium concentrations at Eatons Neck ranged from 280 to 2100 μM. Relative to the bottom waters, the sediments were thus enriched in dissolved ammonia by two or three orders of magnitude. Ammonium profiles often showed a strong maximum at 15 to 20 cm from the top of the core. This maximum may be attributed to the increased input of organic detritus in the last 70 to 100 years. The removal of ammonium in the upper 10 cm may be due to diffusion, bioturbation, or nitrification if an aerobic/anaerobic double layer exists at the sediment/water interface. Table 23 shows a comparison of interstitial ammonia at reference station A and disposal site DSA. There seems to be significantly more (perhaps by a factor of 2) ammonia in the interstitial water at the dredge site, in keeping with the somewhat higher pH.

115. Interstitial silica also showed a considerable enrichment compared to overlying waters, varying from 600 to 1420 μM. The authors of Appendix B stated that in most of the cores, the silica values show "saturation at depth," although they did not indicate how the conclusion was drawn. They concluded that the solubility of silica (silicic acid) was regulated by biogenic opal, since the dissolved values found were higher than the solubility of quartz and common clay minerals.

116. However, based on examination of the data by WES, it appears that the dissolved concentration values may be affected by amorphous silica, which has a pseudo-solubility constant that is an order of magnitude larger than quartz. The rate of crystalization of quartz is often so slow that the upper limit of dissolved silica is normally set by the amorphous form.

117. Interstitial values for dissolved phosphate ranged from 5 to 1287 μM, and some values were similar to those observed for ammonia and total dissolved nitrogen. This suggested to the authors of Appendix B that the processes operative for phosphate regeneration at depth and loss to the overlying waters may be similar to those for ammonia; however, such a conclusion seems highly unwarranted.

118. Interstitial phosphate at reference station A is compared to the disposal site in Table 24. Because of the large variation among the DSA samples, it is difficult to decide whether a significant difference exists. There very likely is not a significant difference.

119. Berner[28] reported concentrations of interstitial phosphate exceeding 10 μM in the surface sediments from New Haven Harbor.

PART VI: BIOLOGICAL STUDIES

Benthos

120. The benthic research at Eatons Neck included studies of macrofauna and meiofauna. The results of the benthic studies are presented in Appendix C. For purposes of this report, only data on the macrofauna collected with the Smith-McIntyre grab from October 1974 thorough April 1975 are treated in detail to provide a general description of assemblages within the boundaries of the Eatons Neck site and the northward extension of the site. In addition, comparisons are made between disposal site stations and reference area or unaffected stations.

Macrofauna

121. Assemblages. The benthic macrofauna at the Eatons Neck site and the northward extension may be divided into three assemblages based on numerical classification procedures and sediment distribution patterns: a mud or silt-clay assemblage; a Budd Reef sand assemblage; and a Cable and Anchor Reef sand assemblage. The large temporal and spatial variation in sediment grain-size data complicated the definition of benthic assemblages, but general distribution patterns were evident. The observed sediment variation is probably attributable to natural patchiness in combination with vessel-positioning error in returning to a given station each sampling period.

a. Mud assemblage. The mud or silt sedimentary facies was distributed over most of the Eatons Neck site (Figure 10), except in the vicinity of reefs. Sediments in the facies ranged in composition from 36 to 98 percent silt-clay with 90 percent of the samples having more than 60 percent fine material (Table 25). The mud macrofaunal assemblage was moderately variable among stations in terms of species composition and total density of organisms, but station differences were generally a matter of degree; mud macrofauna stations were more similar to one another than to sandy reef stations.

(1) Temporal changes in dominant species were evident, based on the abundance index. In October the deposit-feeding polychaete *Mediomastus ambiseta* and oligochaetes were dominants. These species were

also dominants in December and January together with the deposit-feeding polychaete *Nephtys incisa* and the suspension-feeding bivalve *Mulinia lateralis*. The *M. ambiseta* population declined in February and April, and *N. incisa* and *M. lateralis* were the most abundant species.

(2) Total macrofaunal density was large in December and comparatively small in other months (Figure 20), a significant ($P < 0.05$) trend for all stations combined based on the two-way ANOVA. Total density was not significantly different ($P < 0.05$) among the mud assemblage stations. However, there was total density differences among stations for specific sampling times, but the pattern of these differences was not consistent. Also, total density was significantly less ($P < 0.05$) in the mud assemblages than in both sand assemblages. Macrofaunal biomass was consistently small in the mud assemblages and did not exhibit pronounced temporal variation (Figure 21).

(3) The number of macrofaunal taxa collected per station did not vary significantly ($P < 0.05$) with time, regarding the main effects of sampling time (Figure 22). With respect to the main effect of sampling station, the mud assemblage had significantly fewer taxa ($P < 0.05$) than the Cable and Anchor Reef assemblage. However, the number of taxa in the mud and Budd Reef sand assemblages was comparable with station EB9 being equal to stations EB2, EB3, and EB5, and station EB6 being equal to station EB1.

b. Budd Reef sand assemblage. Budd Reef located near the northern corner of the northward extension (Figure 10) had predominantly sand sediments. The sediment samples collected concomitantly with the benthic samples ranged in composition from 19 to 93 percent sand; however, half of the samples from Budd Reef had greater than 70 percent sand (Table 25). Stations EB6 and EB9 were the benthic stations located in the Budd Reef environment.

(1) The deposit-feeding cephalocarid crustacean, *Hutchinsoniella macracantha*, was characteristic of the Budd Reef assemblage in all months, while other dominant species varied with time. Nematodes were a dominant in October; *Mediomastus ambiseta* was a dominant in December; *M. ambiseta* and *Nephyts incisa* were dominants in January; *Polygordius triestinus*, a deposit-feeder, was a dominant in February; and *N. incisa* was a dominant in April. Low total densities from December through April, however, render relative abundance data of little importance for these months.

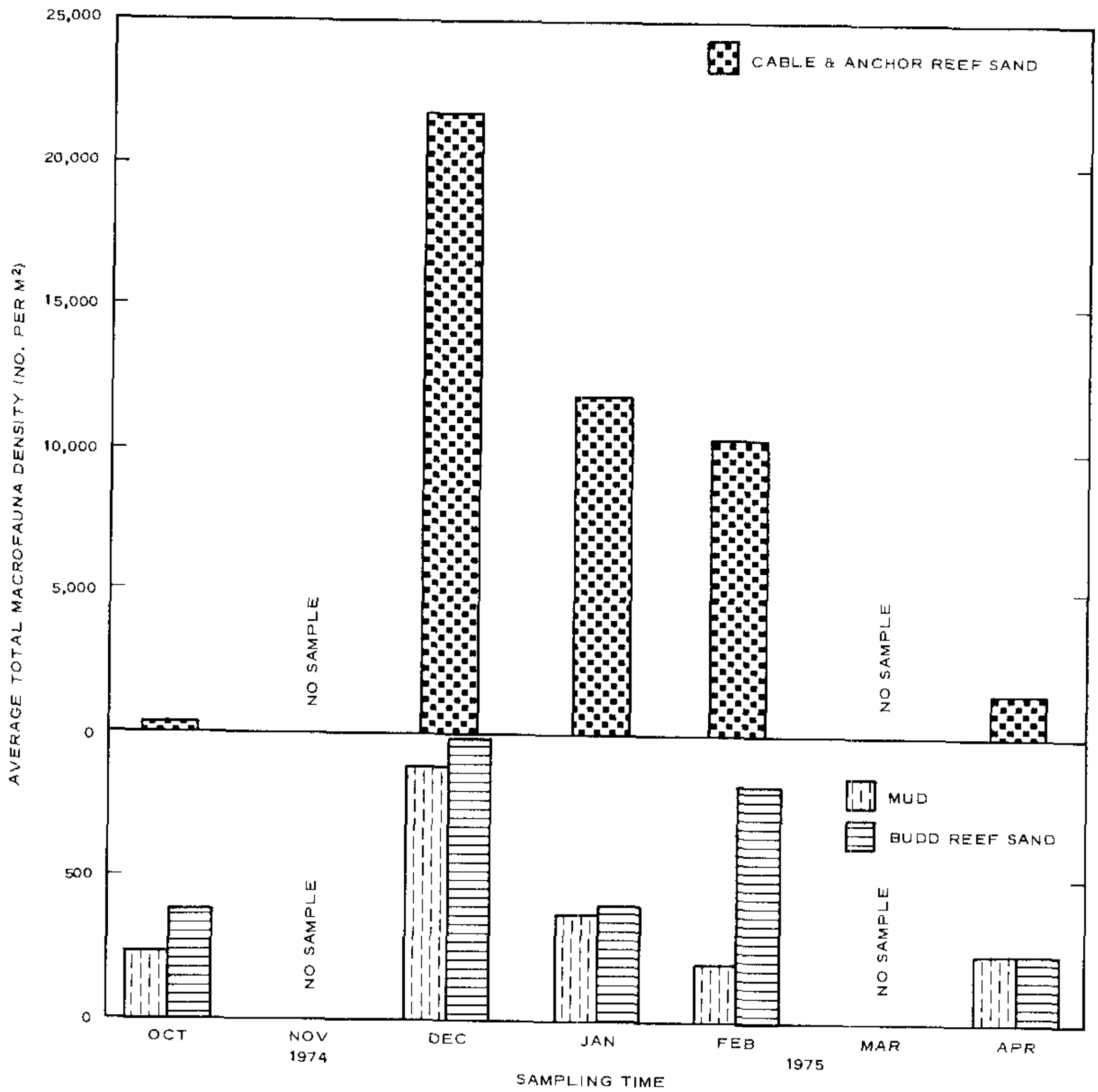


Figure 20. Total benthic macrofaunal density, October 1974-April 1975

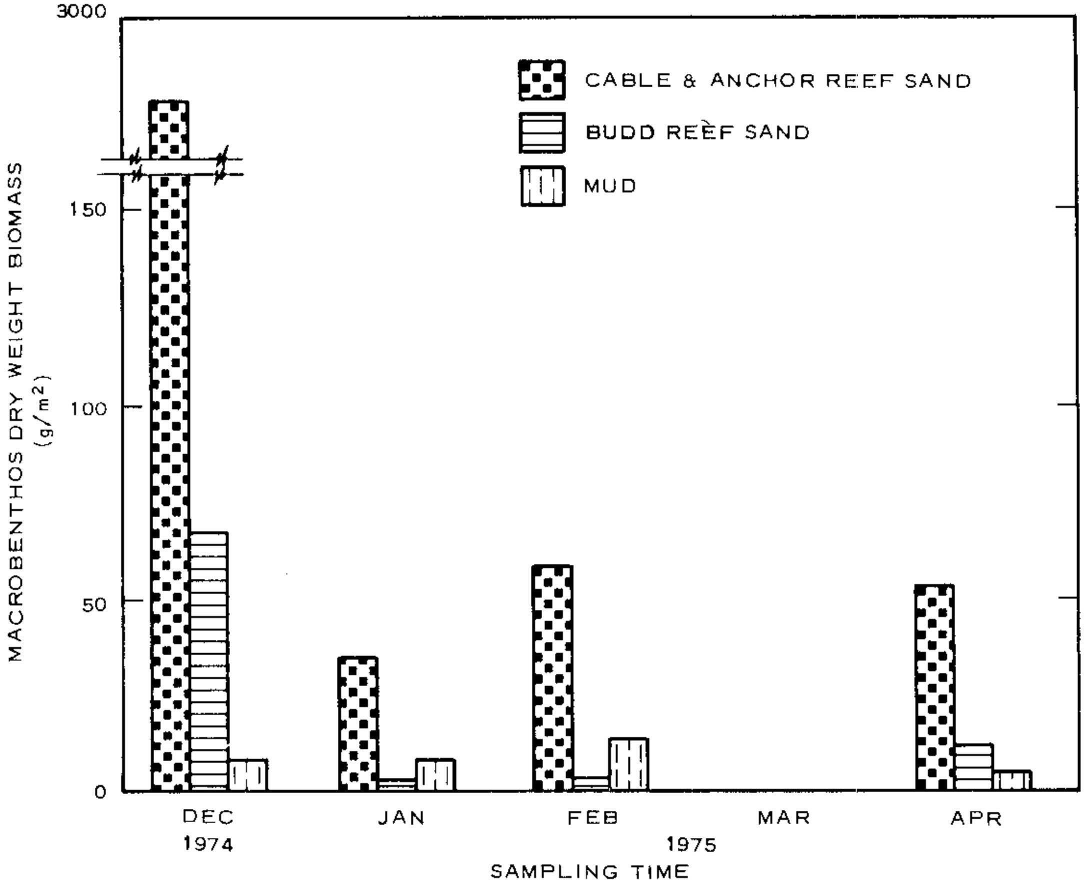


Figure 21. Benthic macrofaunal biomass, October 1974-April 1975

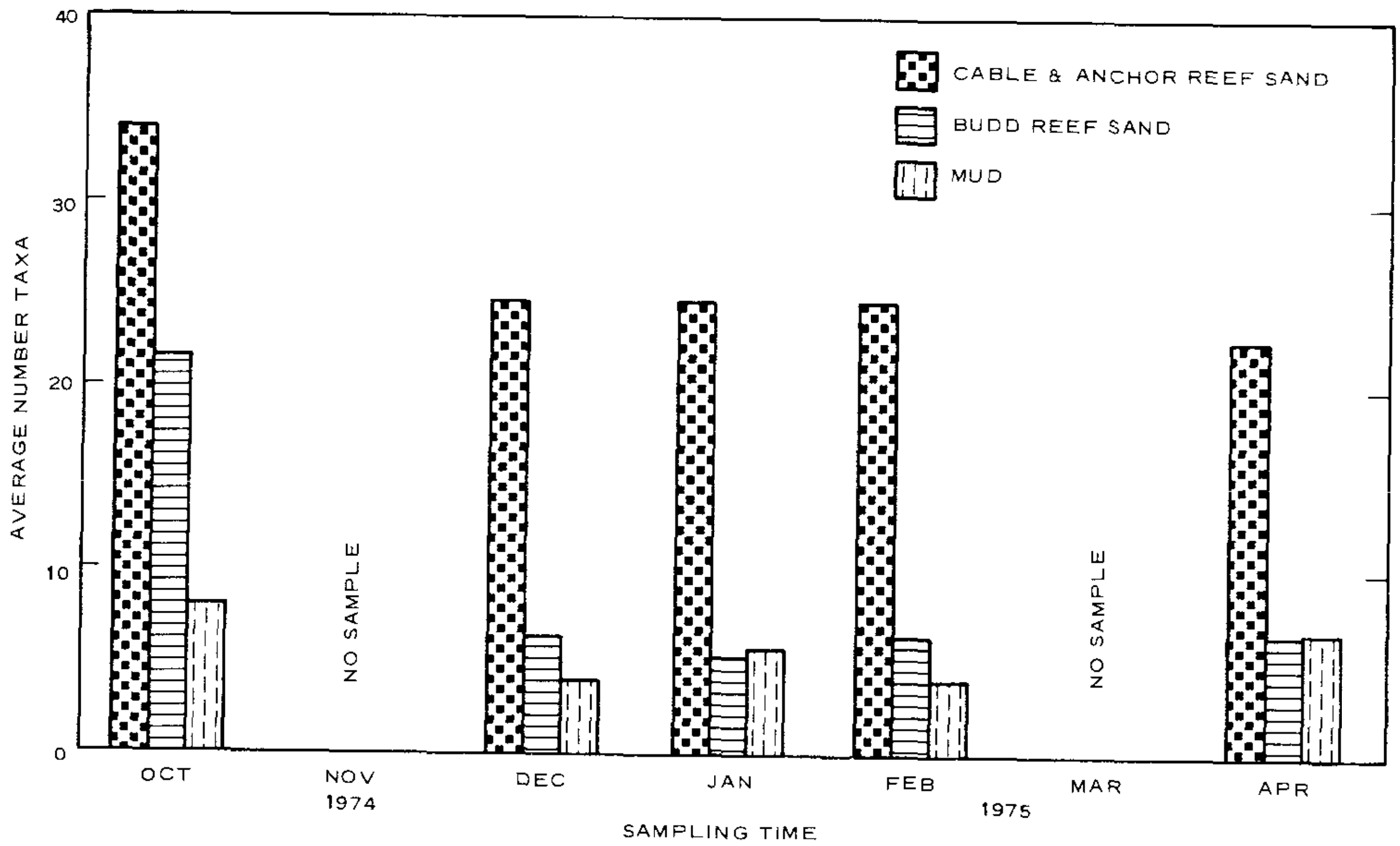


Figure 22. Number of benthic macrofaunal taxa, October 1974-April 1975

(2) Total macrofaunal density was largest in December and had a secondary peak in February (Figure 20). This trend was different from that observed in other assemblages where only the December peak was evident. December macrofaunal density was also statistically greater ($P < 0.05$) for the main effect of sampling time in the two-way ANOVA. Total density was significantly less ($P < 0.05$) for the Budd Reef sand assemblage than for the Cable and Anchor Reef sand environment, while total densities were comparable in the Budd Reef sand and mud assemblages. Macrofaunal biomass levels were similar to those of the mud assemblage, but were noticeably less than in the Cable and Anchor Reef sand assemblage (Figure 21). Number of taxa was largest in October, decreased in December, and remained low through April (Figure 22).

c. Cable and Anchor Reef sand assemblage. The silty sand to silty gravelly sand sediments at Cable and Anchor Reef had the most abundant and diverse macrofaunal assemblage sampled at Eatons Neck. Sediments varied in composition from 53 to 95 percent sand with all but one sample having a composition greater than 60 percent sand (Table 25). Stations EB7 and EB8 were located in the portion of the Cable and Anchor Reef within the site boundaries.

(1) Dominant species varied greatly during the October through April sampling period. Based on the abundance index, *Polygordius triestinus*, a deposit-feeding archiannelid, the polychaete *Aricidea cerruti*, and oligochaetes were the dominants in October. Nematodes dominated in December, while *Nucula proxima*, a deposit-feeding bivalve, and *P. triestinus* dominated in January. Nematodes were the dominant macroinvertebrates in February and April along with several subdominants.

(2) Macrofaunal density was one to two orders of magnitude larger at the Cable and Anchor Reef stations than at the mud and Budd Reef stations, a significant difference ($P < 0.05$). Total density was low in October, reached a maximum in December, and decreased to a second low in April (Figure 20). Biomass, to the contrary, was at an elevated level in December, but was depressed during the other sampling periods (Figure 21). Biomass, however, was markedly greater for the Cable and Anchor Reef assemblages than in the two other assemblages.

(3) The number of macrofaunal taxa in the Cable and Anchor Reef assemblage was several times greater

(P < 0.05) than in the mud and Budd Reef sand assemblages (Figure 22). Temporal changes in number of taxa were small, which is consistent with the nonsignificant (P < 0.05) main effect of time for number of taxa in the two-way ANOVA. Shannon-Weaver species diversity values were also significantly greater (P < 0.05) in the Cable and Anchor Reef sand assemblage than at the combined mud and other sand assemblage stations (Appendix C).

122. Epibenthic sled macrofauna. Macrofauna collected with the epibenthic sled differed somewhat from that collected with the Smith-McIntyre grab. *Mulina lateralis* and *Nucula proxima*, both bivalves; the snail, *Nassarius trivittatus;* and the crustacenas *Crangon septemspinosa*, *Pagurus longicarpus*, and *Neomysis americanus* were the numerically dominant species in both the sand and mud sedimentary environments at Eatons Neck. Station differences were mainly in the relative abundances of these dominant forms. Large numbers of specimens were obtained with the epibenthic sled; however, due to the qualitative nature of the device, no attempts were made to quantify temporal and spatial distribution patterns. Temporal fluctuations in sled catch-per-unit-effort were primarily as result of variations in *Mulinia lateralis* numbers. Catches were large in December, decreased in February, and were large again in April and May. Shannon-Weaver diversity index values were consistently lower for sled samples than for bottom grab samples because of the dominance of the sled samples by one species, *M. lateralis*.

Meiofauna

123. Total meiofaunal density ranged from 1 to 2,841 organisms per 10 cm^2 in the upper 10 cm of sediment, but were generally less than 200 per 10 cm^2. Densities were greatest in sand environments. Nematodes were the dominant constituents of the meiofauna, comprising 45 to 100 percent of these organisms. Harpacticoid copepods were second in numerical abundance, making up as much as 39 percent of the meiofauna. The meiofauna density was generally less than that reported for other estuaries in the northeast, but the taxonomic composition was similar to reported values.[29, 30, 31]

Comparisons to other disposal sites

124. Detailed comparisons of the macrofauna inhabiting the Eatons Neck site with that reported for other Long Island Sound disposal sites, particularly the New Haven site, could not be made because of differences in sampling devices, mesh size of sieves used to separate organisms from the sediments, level of taxonomic identifications, and the different periods of time the various sites were sampled following a disposal operation.

Effects of dredged material disposal

125. Evaluation of the effects of past dredged material disposal on the macrofauna at Eatons Neck must be done with caution. First, approximately four years elapsed between the last disposal operations at the site and the collection of the benthic data. Thus, other perturbations or natural long-term changes other than disposal effects could have influenced the benthos. Secondly, there is no predisposal baseline data for the site. Thirdly, the spatial coverage of reference stations is not adequate for placing the disposal site benthic community in perspective regarding the surrounding area of the sound. Consequently, it is not known if the benthic data collected is representative of the surrounding area of the sound.

126. For purposes of this evaluation, all benthic stations sampled in the Eatons Neck disposal site (excluding the northward extension) were assumed to be on dredged material, except EB2. Thus stations EB1, EB4, EB7, and EB8 were classified as affected by dredged material and stations EB2, EB3, and EB10 were classified as unaffected. The classification of stations is predicated on the distribution map of the dredged material deposit given in Figure 10. However, it was not determined if each benthic sample contained dredged material.

127. For October 1974, two macrofaunal assemblages were defined within the disposal site using numerical classification: the mud assemblage comprised of site groups A, B, and F, and the Cable and Anchor Reef sand assemblage comprised of site group C. The Budd Reef sand assemblage did not occur within the bounds of the disposal site. Three of these site groups, A, B, and C, contained both disposal site

and reference stations, indicating similarity in macrofaunal abundance and species composition between areas within and outside of the disposal site in October. Assemblage F was a group of three mud stations in the disposal area that clustered separately from other stations due to their relatively greater density of constituent species. Numerical classification of the December through April macrofauna data also indicated that both disposal site and unaffected mud and sand stations had similar macrofaunal assemblages (Appendix C).

128. Statistical comparisons were made of the December through April total density and number of taxa data between disposal site and unaffected stations. Results of these tests (Table 26) revealed few significant differences between disposal site and reference stations, and these were not temporally consistant.

129. It is concluded, therefore, based on these results, that there was no major difference during the study period between macrofaunal assemblages of the Eatons Neck disposal site and nearby areas outside of the site as represented by the reference or unaffected stations. Species composition and total density generally appeared similar between areas that had been disposed on and those that had not, while in some instances levels were greater in the disposal site. The relatively low macrofaunal diversity and total density of the mud assemblage suggests a stressed environment (Appendix C). However, since this pattern was observed for both the disposal site and areas to the east and west of the site, these characteristics cannot be attributed specifically to dredged material disposal, but may reflect other man-induced perturbations or natural conditions.

Phytoplankton

130. The dominant species comprising the phytoplankton at Eatons Neck varied temporally. Phytoplankton was dominated in October by the diatoms *Prorocentrum redfieldii*, *Thalassionema nitzschiodes*, *Skeletonema costatum*, and *Thalassiosara* spp. at stations EN1 and EN3;

Chrysocromulina sp. was also a dominant at station EN2 together with these species. From November through February, *T. nitzschioides* was the most abundant phytoplankter while during March and April, *Thalassiosira nordenskioldii* was dominant. *T. nitzschioides* and *Ebria tripartita* were the most abundant species in May; unidentified flagellates dominated the May phytoplankton.

131. Phytoplankton density was relatively low from October through February, peaked in March (the spring diatom increase) and June, and decreased concentrations occurred in April and May (Figure 23). There was little vertical or horizontal variation in phytoplankton populations for a given sampling time, although surface water phytoplankton densities were usually larger than mid-depth and near-bottom densities. Species diversity values were largest in October, declined during winter, and increased in the spring in correspondence with the spring bloom. Differences in species diversity among sampling stations were small. Results of the phytoplankton studies are contained in Appendix F.

Zooplankton

Holoplankton

132. Copepods composed over 90 percent of the holoplankton in all months sampled. *Acartia tonsa* was the dominant species from December through February, whereas *A. clausii* was the most abundant holoplankter from March through June. *Temora longicornis* was a subdominant species from January through June.

133. Copepod numbers were low in October and November, increased several times in mid-December, and reached a maximum in April, May, and June. The December population increase, mainly the effect of rising *Acartia tonsa* concentrations, was associated with a three-fold enlargement of phytoplankton numbers (Figure 23). Thus the hypothesis that the December copepod increase is a paradox because it preceded the spring phytoplankton bloom (Appendix E, p. 44) appears questionable, although the December phytoplankton increase is comparatively small.

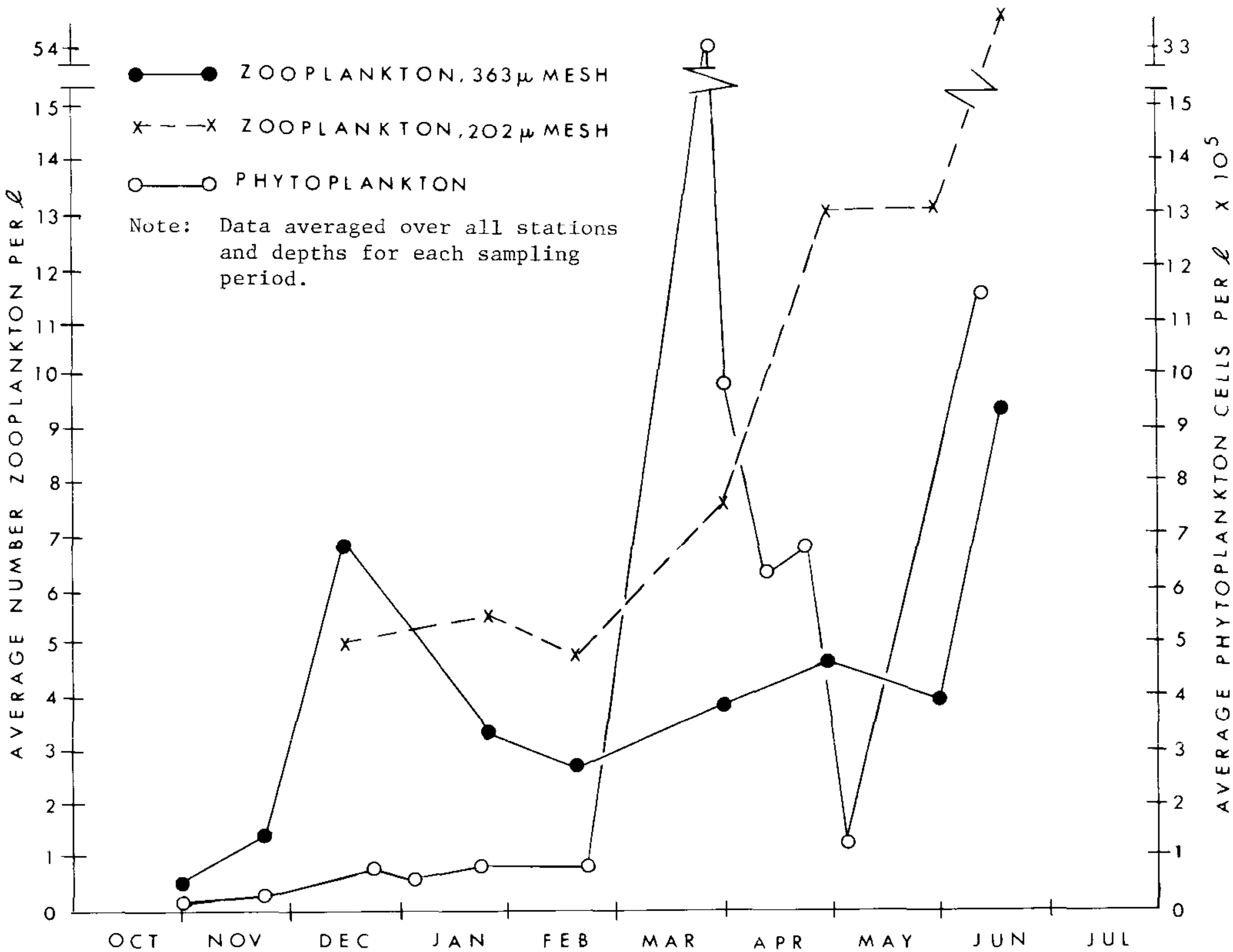


Figure 23. Total standing crop of zooplankton and phytoplankton, October 1974-June 1975

Also, the December increase happened 13 weeks prior to the spring phytoplankton bloom, not 6 weeks as stated in Appendix E, p. 61.

134. The maximum abundance of copepods was observed following the spring phytoplankton bloom. The change in dominant species from the characteristically winter form, *Acartia tonsa*, to the spring-summer form, *A. clausii*, likewise took place during the spring bloom. *Acartia* copepodites were most abundant following the phytoplankton maximum in March as well. However, the sharp December increase in copepodites depicted in Appendix E, Figure E6, is an artifact, since only the 363-μ mesh net, which catches few copepodites, was used in October and November, while the 202-μ mesh net, which collects relatively large numbers of copepodites, was used for the remaining sampling periods. The spring copepod maximum is probably related to increased food supply, warming water temperatures, and the hatching of resting eggs that overwintered in bottom sediments.

135. Total zooplankton biomass was least in October and increased steadily in abundance through June. No pronounced peaks in zooplankton biomass were measured in spring simultaneous with the observed density maxima. However, the zooplankton biomass values represent both holoplankton and meroplankton in addition to certain amounts of phytoplankton and detritus that may dampen actual temporal fluctuations in a given component.

Invertebrate meroplankton

136. Larvae of crabs, caridean shrimp, barnacles, clams, and snails were abundant in the zooplankton. Crab and shrimp larvae were most numerous from April through June, while barnacle nauplii were common during winter and spring. Gastropod and bivalve larvae were also most abundant in spring. Even though polychaetes were the dominant component of the benthic community, their larval stages were less numerous in the plankton than have been reported from other studies in the sound (Appendix E). Larval polychaete numbers were greatest in spring.

Ichthyoplankton

137. Fish eggs and larvae were not abundant during the winter months, although the beginning of winter flounder and fourbearded rockling spawning activity was evident. During early spring, water temperatures rose rapidly (about 1.5°C per day) and fish spawning increased, particularly for the fourbearded rockling and winter flounder, which had spawning peaks during this time. The total number of fish eggs and larvae was maximum in late spring with several pelagic species (menhaden, mackeral, anchovy) and demersal species (cunner, windowpane flounder, blackfish, and others) exhibiting peak reproductive activity.

Demersal Fish

Temporal and spatial patterns

138. The discussion of the fish data will focus on data for dominant species from stations EF1, EF3, and EF4; limited attention is given to station EF2 because sampling at this location was discontinued after four months. Stations EF1 and EF2 were not located within the boundaries of the Eatons Neck disposal site but were approximately one mile north of the site. Thus, station EF4 was the only experimental station actually within the site boundaries (Figure 9). During the 8-month sampling period, 5489 fish were collected representing 37 species from both resident and migratory populations found in Long Island Sound. The five most abundant species made up 94 percent of the catch. Twenty-three species of fish were collected fewer than ten times during the sampling period. Of the three major sampling stations, station EF1 had the largest total catch (1808 fish); station EF3 had the second highest catch (1493 fish); and station EF4 had the smallest catch (1128 fish). The relatively low catch at station EF4 is partly due to the fact that this station was not sampled on the first sampling date.

139. The three most abundant species, windowpane flounder *(Scophthalmus aquosus)*, winter flounder *(Psuedopleuronectes americanus)*, and red hake *(Urophysis chuss)*, made up 54, 26, and 8 percent of the

catch, respectively. Combined, they represent 88 percent of the total catch. The dominant fish at Eatons Neck are similar to those previously reported from the sound[32] and Narragansett Bay.[33] Peak catches occurred during early and mid-April for windowpane flounder, during January for winter flounder, and during June for red hake. In general, windowpane and winter flounder, resident species, were more abundant during the period of low water temperature, and the migratory red hake was most abundant in June when water temperatures were higher.

140. Temporal trends in total catch were similar for stations EF1 and EF4 with larger catches occurring in the colder winter months (December through February) and lower catches occurring during the warmer spring and summer months (Figure 24). Station EF3 differed from the other two stations in that total catch began to increase in April and peaked for the study period in June. This difference in total catch over time between station EF3 and stations EF1 and EF4 was apparently due to station differences in the three most abundant species (Appendix D). Windowpane and winter flounder were more abundant at stations EF1 and EF4 during the winter months whereas the red hake influx in the spring was more noticeable at stations EF3.

141. Catch weight data showed similar patterns to that of catch numbers (Figure 25). The total average weight per catch from all stations combined for the 8-month sampling period was 475 kg. The largest catch for a particular month (80 kg) was taken in January with station EF1 making up 32 kg of the sample. Catch weight data differed for catch number data in that EF3 produced the largest total catch (187 kg) for the study period and EF1 had the second largest (176 kg). Windowpane flounder accounted for 56 percent of the total weight landed. The other two dominant fish, winter flounder and red hake, made up 20 and 6 percent of the total catch.

Food habits

142. The stomach contents of several species of benthic-feeding fish were analyzed. Windowpane flounder was found to be a highly selective feeder in that stomach contents showed a fairly constant diet of *Neomysis americana*. There was no apparent difference among stations

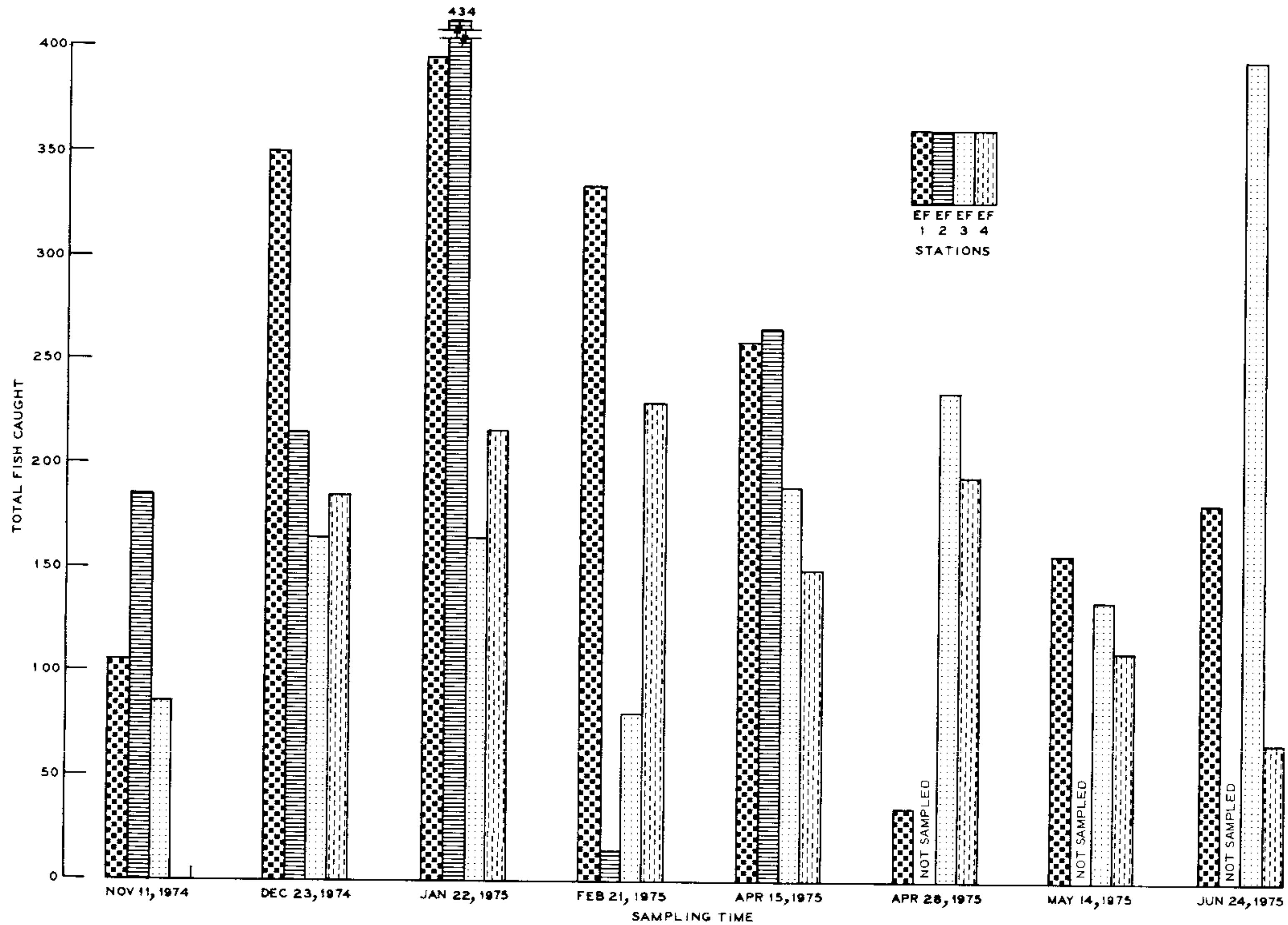


Figure 24. Temporal and spatial distribution of demersal fish catches, November 1974-June 1975

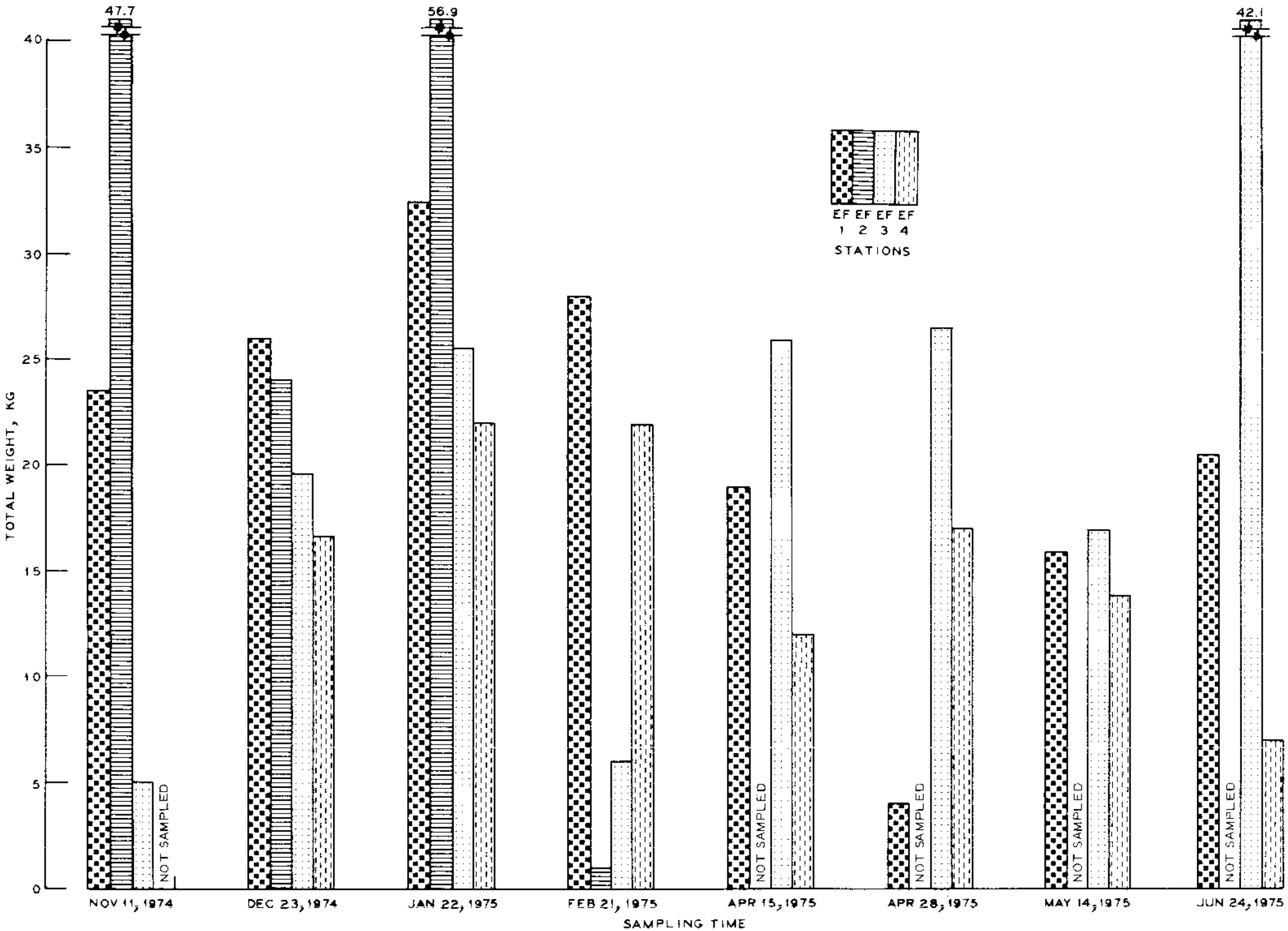


Figure 25. Temporal and spatial distribution of fish biomass, November 1974-June 1975

in stomach content for this flounder. The mean percentage of *Neomysis* over all sampling dates for the three stations examined ranged from 97 percent for station EF3 to 95 percent for station EF1. The second most dominant food item of winter flounder was *Crangon septemspinosa*. Again, this food item was found commonly in specimens collected at all stations.

143. Winter flounder were found to be less selective feeders than windowpane flounder. Stomach contents of winter flounder consisted mostly of *Anemone* sp. and the polychaete *Pherusa affinis*, cut some difference among stations was evident in the diet. *Anemone* sp. was the dominant food item for specimens collected at station EF3, composing 70 percent of the diet, and *Pherusa* only constituted 20 percent of the diet. *Pherusa* was the most abundant food item at disposal site stations EF1 and EF4, comprising 34 and 41 percent of the diet, respectively. *Anemone* sp. constituted 22 percent of the winter flounder's diet at station EF1 and 26 percent of the diet at station EF4.

144. Stomach content data for the other benthic feeding fishes collected during the study are discussed in Appendix D. These data show occasional differences among stations in food habits for certain species. Also, the ratio of fish with empty stomachs collected at the disposal site stations to station EF3 varied with different species and over time.

Community structure

145. To determine if there were differences in fish community structure (as defined by the trawl data) among sampling stations, the Shannon Index of species diversity ($\bar{H}$) was computed. The values for $\bar{H}$ ranged from a low of 0.82 for station EF3 on 28 April 1975, to a high of 2.52 for the same station on 23 December 1974 (Figure 26). The widest range (1.19 vs 2.52) between stations for a given month was between EF3 and EF1 in December 1974 and between EF4 and EF3 (0.82 vs 2.12) on 28 April 1975. Overall, $\bar{H}$ oscillated from a low of about 1 to a high of slightly above 2. There appeared to be no obvious temporal trends or patterns in species diversity differences among stations. This apparent spatial similarity in $\bar{H}$ may be due to insufficient replicate samples and the infrequent sampling schedule.

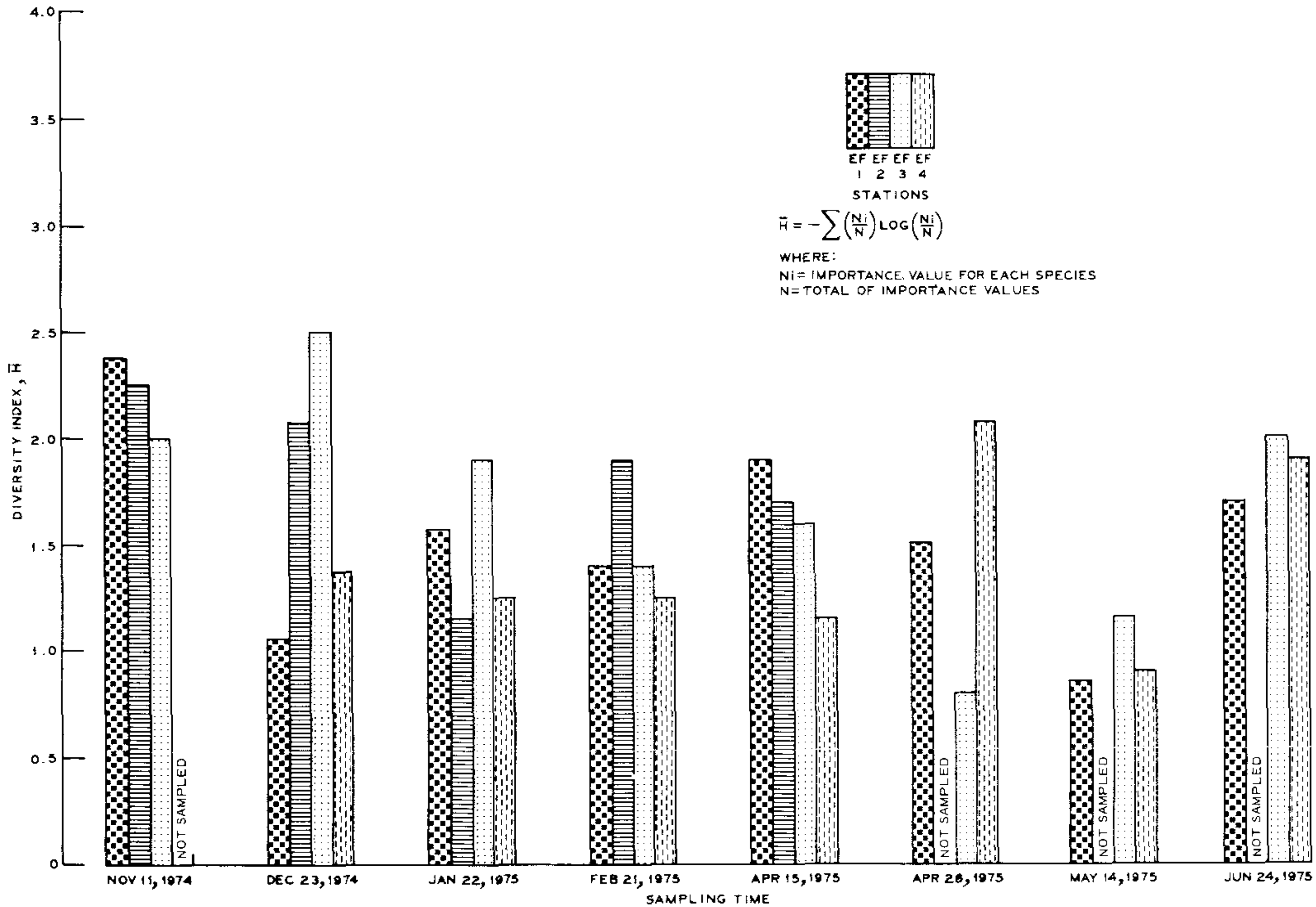


Figure 26. Temporal and spatial distribution of fish species diversity index values, November 1974-June 1975

Fish length

146. Analyses of length frequency data was conducted by WES for the two dominant fishes, windowpane flounder and winter flounder (Table 27). There were no apparent differences in mean lengths for either fish species among stations. However, one-way ANOVA of winter flounder length data for specific stations did show some differences over time. In general, winter flounder mean length decreased significantly from December 1974 to February 1975, increasing to December levels in April. Mean length then remained stable throughout the spring sampling period. No trends over time were detectable for windowpane flounder.

Lobsters

Fishery

147. The Eatons Neck area supports a large commercial lobster fishery relative to the remainder of Long Island Sound. The intensity of lobstering is greatest in May and June. The summer (April through October) lobstering ground encompasses most of the Eatons Neck disposal site; in winter (November through March), the intensity of commercial lobstering is shifted eastward and the lobstering ground encompasses only a portion of the site (Figure 27).

148. The commercially important concentration of lobsters at Eatons Neck is probably a result of the presence of plentiful cover in the form of cohesive substrata suitable for burrowing, sharply irregular bottom topography, and the presence of various debris on the bottom. This cover consists mainly of dredged material, wrecked ships, and building rubble. Lobsters require shelter such as borrows in cohesive sediments, under rocks, or similar habitat. Burrows and other shelter are occupied by the lobsters during daytime while they leave them at night to forage.[34]

Catches

149. Trawling at Eatons Neck sampling stations produced 416 lobsters. Largest monthly catches were taken from December through June (Figure 28). Forty-two percent of the catch was from station EF4

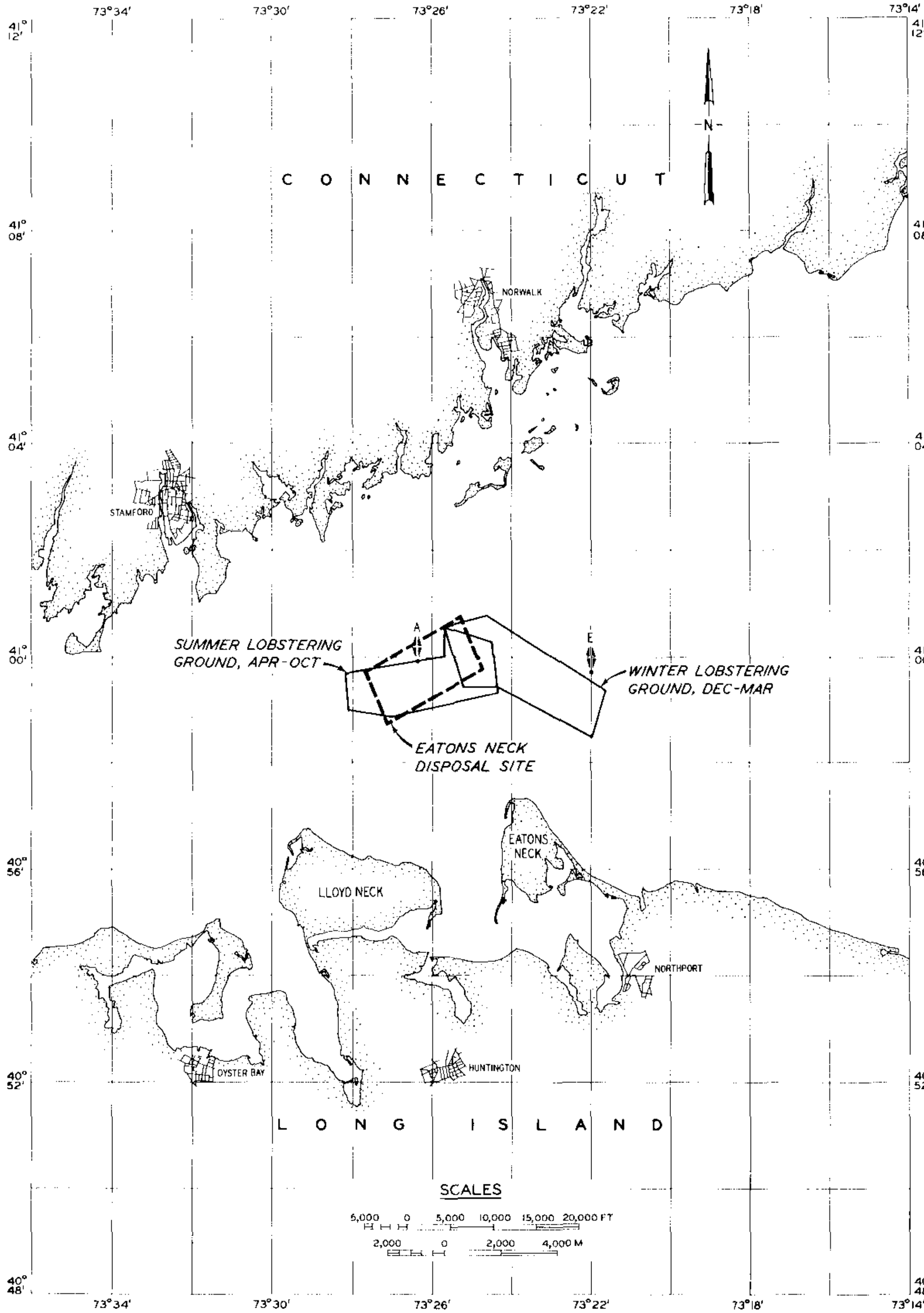


Figure 27. Seasonal commercial lobstering grounds in the vicinity of the Eatons Neck Disposal Site

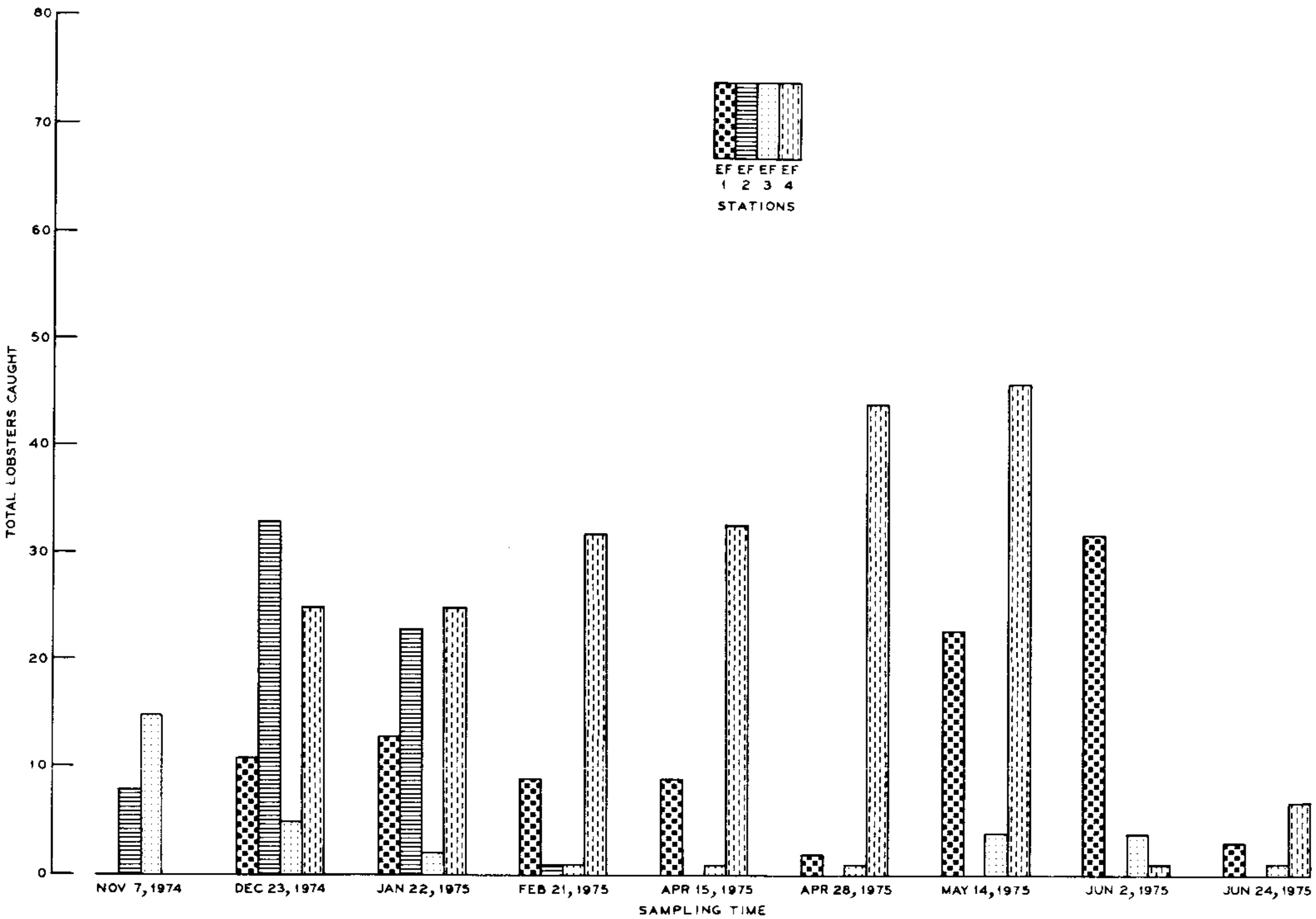


Figure 28. Temporal and spatial distribution of lobster catches, November 1974-June 1975

located in the disposal site. Stations EF1 and EF2, both located immediately northwest of the disposal site, produced the next largest catches (24 and 14 percent of the total catch). Had station EF2 been sampled throughout the study period, it would probably have yielded a much greater percentage of the catch. Station EF3 located approximately east of the disposal site had the smallest total catch (36).

150. The amount of commercial lobstering at the site (based on the number of lobster pots present) followed the same temporal pattern as the trawl catches. Station EF2 in the site had the largest amount of commercial fishing effort and produced the most number of legal-sized lobsters (carapace length > 81 mm) during the study. The commercial fishing effort was small at reference station EF3.

Construction of habitat

151. Two prior studies, one at the New London disposal site[35] and one at the New Haven disposal site, indicated a potential for using dredged material to construct lobster habitat. The feasibility of this approach was demonstrated off the south shore of Long Island using rock and building rubble,[36] and in the Northumberland Strait of eastern Canada using sandstone.[37] Lobster habitat development has also been proposed as a productive use of dredged material.[38]

Heavy metal concentrations

152. Lobsters were collected on 2 June 1975 from station EF1 and station EF3 for analysis of heavy metal concentrations in tissues. Lobsters used in the analysis ranged in size from 67- to 104-mm carapace length with no apparent difference between the two stations. Gills, digestive diverticulum, and tail muscle of 15 specimens from EF1 and 5 species from EF3 were separately analyzed for concentration of silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and lead (Pb). Results of the analyses of the digestive diverticulum were not significantly different ($P < 0.05$) between the two stations. Levels of chromium, nickel, and lead in the digestive diverticulum were generally below detection limits for all tested individuals; consequently, no statistical conclusions could be drawn from the data. Similar results were observed for metal concentrations in gill tissues and in tail

muscle tissues, the edible portion of the lobster. The Food and Drug Administration (FDA) standard of 0.5 ppm cadmium in fish and shellfish was not exceeded in the edible tail muscle of any lobsters from either station.

153. Similar levels of heavy metals have been reported in lobsters from the New London and New Haven dredged material disposal areas. The only differences were that Eatons Neck lobsters appear to have higher levels in the digestive diverticulum; however, when compared to Bryan's work on the hepato-pancreas of *Homarus vulgarus* from British waters, the levels appear to fall within the reported range for the genus *Homarus*.[39] Bryan reported mean levels in *H. vulgarus* of approximately 68 to 1150 mg/g for copper and a range of 30-90 mg/g for zinc.[39]

PART VII: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Physical Studies

Dredged material dispersion

154. No physical evidence of significant dispersion of disposed material from the designated site was documented. The continued presence of disposal mounds and rough microtopography is evidence that no large-scale transport is occurring. Comparisons between bathymetric surveys taken over two years apart substantiates this conclusion.

Currents

155. Prevalent rotary tidal currents, much elongated along the semi-major axis of the sound, are dominated by the semi-diurnal M_2 (lunar) constituent and shallow-water harmonics. Current velocities 2 m above the bottom are typically less than 30 cm/sec, although on rare occasion, storm-associated velocities above 50 cm/sec may be observed. The net tidal cycle displacement of near-bottom water was found to be fairly consistent, with flow towards the west or southwest at speeds less than 6 cm/sec. Shoreward net flow was not observed. Perturbations of the net flow were found to increase during stormy periods and are thought to be a result of the passage of eddies or meteorological disturbances. Bottom orbital velocities associated with wind-generated waves are thought to have little effect on resuspending disposal material because of the deep water depths at this site.

156. Cable and Anchor Reef, located northeast of the disposal site, was found to influence the water-flow characteristics of the surrounding area. Flow interruption caused by the reef may result in a relative deficiency in the amount of water transported downstream behind the reef during the flood tide, while during the ebb tide a pile-up of water may occur. Information obtained from three current-meter stations, up to three miles west of the reef, substantiates this bathymetric influence or shielding. The reduced flow associated with Cable and Anchor Reef may result in an environment favorable for the placement and retention of dredged material.

157. On the basis of the geologic and physical information obtained, it is concluded that the Eatons Neck site is a suitable open-water disposal site where sediment dispersion will be minimal.

Chemical Studies

Seasonal and spatial distribution of water-column data

158. Taken together, the averaged water column data from the Eatons Neck study represents the late fall-to-spring portion of the annual cycle of water column stability, nutrients, and phytoplankton concentrations observed by Riley[40, 41] in Long Island Sound.

159. Temperature. Water-column temperature was uniform with depth until late April, when spring warming was evident in the surface layer. By 28 May, there was thermal stratification, ranging from less than $11^{\circ}C$ below 16 m to greater than $15^{\circ}C$ near the surface.

160. Salinity. Average salinity was relatively uniform with depth on all cruises until 28 May, when a halocline was observed. A weak pycnocline was found beginning in January, probably due to the small depth variation in salinity. By May, both the slightly increased halocline and much intensified thermocline combined to produce a more pronounced density stratification. There was a general increase in surface salinity eastwards, probably caused by river discharge into the sound.

161. Nutrients. Relatively high but uniform concentrations of nutrients existed until April and May, when concentrations in the surface layers decreased. By 20 May, the average water-column concentrations of nitrate and ammonia had fallen below 0.5 μM in the surface layer. However, data on nitrate were somewhat ambiguous; no significant differences were evident between reference station A and disposal site DSA. Gradients in ammonia were found, probably affected by sewage effluents.

162. The effect of the presence of dredged material on the bottom was not demonstrable in surface waters; however, concentrations were

higher in the interstitial water at the disposal site than at reference station A. Silica levels declined to below 5 μM in the surface layer during April and May. Gradients for silicic acid increased to the north and west in January and March; no gradients were evident in May. The analytical data on phosphorus were questionable with little difference noted between reference station A and the disposal site.

163. The spring decline in mean nutrient concentrations was accompanied by increased water column stability, and increasing mean water column concentrations of chlorophyll a. Two blooms of algae were observed (March and May). Little difference was noted between reference station A and the disposal site in January, March, and May for chlorophyll a levels.

164. Particulate carbon and particulate nitrogen increased from low values during the winter period to much higher concentrations during the time corresponding to that of increased water column stability, declining nutrient concentrations, and increasing chlorophyll a values. Little difference was found between reference station A and the disposal site in January for particulate carbon levels. Slightly higher concentrations existed at the disposal site in March while higher levels were found at the disposal site in bottom waters during May. Particulate nitrogen concentrations were essentially the same at reference station A and the disposal site in January; higher levels occurred at the disposal site in March and at the disposal site in bottom waters during May.

165. Dissolved and particulate metals. The first time the authors of Appendix B discussed dissolved metals in the water column, they indicated that "in general, the distribution of dissolved metals showed very little temporal or spatial variation greater than the analytical error...lead and cadmium were the only metals whose concentrations at the western end of the study area were slightly elevated above those observed at the eastern end of the transect." In their summary (Appendix B, p. 192), they pointed out that lead, copper, manganese, and zinc were all greater at the western end (station Y) than the eastern end (station V) during the January cruise. In February, a similar pattern

was observed, but with concentrations of cadmium and iron now greater at the western end. During a phytoplankton bloom (late March), there was essentially no difference between the dissolved metals concentrations in the water column at stations Y and Z.

166. The increased concentrations of dissolved metals at the western end of the sampling area during January and February were probably due to input from the East River--Western Long Island Sound system. Decreased concentrations at station Y during a bloom period suggested that biological processes may be important in the removal of metals for the western end. The March cruise occurred during periods of peak chlorophyll a concentrations and low dissolved metals at the western end. Maximum concentrations of suspended silver, copper, chromium, and iron were observed during the same period, along with suspended nitrogen and suspended carbon. Concentrations of suspended lead and manganese showed a relatively steady increase from 13 Janaury to 28 May.

167. No apparent significant differences between reference station A and the disposal site were found regarding concentrations of dissolved and particulate levels of metal species. It should be noted, however, that the water column data were averaged over all stations sampled on a cruise for a given depth and then contoured spatially. The interpretation based on this form of reduced data ignores hourly variations, possibly due to tidal influence, and makes interpretations difficult.

168. Summary. The chemical studies at Eatons Neck represent a necessarily limited survey of a selected portion of Long Island Sound. Moreover, it is not entirely clear that daily temporal variations were adequately separated from spatial variations for some variables, and some of the data (e.g., phosphate and suspended solids) are questionable. A number of parameters were quite variable within the disposal site. The effects of water column constituents of dredged material disposal at Eatons Neck must be evaluated by comparing the values of parameters at the reference site with those at the disposal site. Any conclusions need to be viewed with these constraints in mind.

169. A number of water column variables showed gradients of various types; however, it seems that most cases can be explained by

factors other than the presence of dredged material. First, salinity patterns demonstrate that water quality in the sound is affected by discharges from the Hudson, Norwalk, and Saugatuck rivers. These fresh waters contain sewage effluent, and this could explain the observed gradients of nutrients (such as ammonia, phosphate, and nitrate) in the water column. In addition, there seemed to be little difference in these water column variables between reference station A and disposal site DSA. Particulate carbon and particulate nitrogen in the water column were slightly higher at the disposal site than at reference station A in March and May. These differences could be due to the general gradient increase westwards in the sound at these times, rather than the presence of dredged material.

170. There were probably no major differences in chlorophyll *a*, dissolved oxygen, dissolved metals, or suspended metals between reference station A and disposal site station DSA during the period of the study.

Seasonal and spatial distribution of sediment

171. Texture and mineralogy. The sediments in the disposal area were found to be mainly silt, with minor concentrations of clay and sand. At the reference site, the sediments were sandy mud with silt dominant. To the east of the reference station, the sediment graded to clayey silt or fine mud with practically no sand fraction. Relative to the disposal area, the sediments at the reference station are more fine grained in the 0- to 10-cm layer. The relative percentage of clay minerals at the reference station did not differ significantly from that at the disposal site. Most of the cores from the disposal area had a hydrogen sulfide odor.

172. Chemistry.

- a. The total carbon and nitrogen content of the near-surface sediments are similar in both areas.
- b. No significant differences between the concentrations of total carbon and nitrogen at the reference sites and the dredge disposal sites were found.

c. Zinc, lead, copper, and mercury in the sediments showed a negative relationship with depth; iron, manganese, and nickel showed little relationship.

d. All metals exhibited strong statistical correlation with the organic fraction of the sediments.

e. All metals except cadmium and mercury showed a positive correlation with the total iron content of the sediment.

f. All metals were strongly associated with each other, and, except for cadmium, with the total CEC of the sediment.

g. There was some association between the metals and the oil and grease content of the sediment.

h. Most of the organic matter was associated with the mud fraction of the sediments, which might explain the positive relationship between metal content and mud fraction.

i. Interstitial metals showed some correlation with other sediment parameters, but no systematic trends were discovered. None of the metals seemed to be associated with the dissolved organic carbon content. Interstitial metals concentrations exhibited some trend with sediment depth.

j. Slightly higher pH levels occurred in surface layers at disposal site DSA than at other stations.

k. Slightly lower amounts of organic carbon were found at reference station A compared to disposal site DSA.

l. Significantly higher concentrations of ammonia were recorded in interstitial water at disposal site DSA as compared to reference station A.

m. No significant difference was noted between reference station A and disposal site DSA for oil and grease.

n. No significant difference among stations was reported; values at reference station A were within the range of those at disposal site DSA.

o. No significant difference was evident among stations regarding metals concentrations, with the possible exception of Mn and Zn.

p. No significant difference was found between reference station A and disposal site DSA for interstitial water metals levels.

173. *Summary.* There were no significant differences between reference station A and the disposal site for sediment mineralogy, total metals, interstitial metals, oil and grease, and CEC. Ammonia,

organic carbon, organic nitrogen, and pH were all higher at the disposal site. Taken together, this probably means a discernible difference in the amount of organic matter and related degradation products in the sediments between the two sites. This difference can be attributed to dredged material disposal. It has not caused any significant oxygen depletion at the disposal site compared to the reference station.

174. It appears that any effect of dredged material disposal on the nutrient, metals, and related parameters in the sound are minimal and are for the most part overshadowed by the effects of sewage effluents and other inputs from river discharge.

Biological Studies

175. There were few significant differences in the abundance and composition of the benthic macrofauna between sampling stations located within the dredged material deposit at the Eatons Neck site (as defined by the geological studies) and those located outside of the dredged material deposit. Further, the relatively small abundance and low diversity of the mud assemblage found both within the outside of the disposal site indicates possible effects of man-induced perturbations other than dredged material disposal or natural conditions. These results suggest that the presence of dredged material was not having significant adverse effects on the benthic community four years after disposal operations had ceased at the site. The restricted spatial coverage of sampling stations outside of the site, however, limits these generalizations.

176. In the future, dredged material should probably be deposited in the mud assemblage located in the western and central portions of the site on predominantly silty sediments because (a) this assemblage has significantly lower benthic abundance and diversity values than found at the Cable and Anchor Reef sand assemblage in the eastern portion of the site, and (b) most sediments disposed of at the site are fine textured, which would probably enable the mud assemblage to recover more rapidly from disposal effects than the sand assemblage.

177. Because of the high spatial variability of plankton populations and the lack of replicate samples for estimating variation, it was not possible to make valid estimates of differences among disposal site stations and those located outside of the site. However, no consistent major differences among stations were noted. Also, because of the lack of toxic water chemistry conditions at the disposal site, it is not expected that the water chemistry of the site adversely affects plankton organisms.

178. It is recommended that research be conducted at the site to determine amounts and abundance patterns of copepod resting eggs in the bottom sediments at Eatons Neck. The productions of demersal eggs by dominant estuarine copepods, including the dominant species in Long Island Sound, is postulated to be an important facet of the reproductive cycle. Dredged material disposal at key times of the year could result in mortalities of benthic copepod resting eggs.

179. The Eatons Neck disposal site is the major lobstering ground in Long Island Sound. The abundance of lobsters is probably attributable to the presence of plentiful amounts of substrata for burrow construction in the form of dredged material, building rubble, and other substances. The abundance of lobsters at the site indicates that the presence of dredged material has not had a major adverse effect on the lobster population, but rather has had a beneficial effect. Moreover, since lobsters are benthic feeders, the benthic assemblages of the site must be sufficiently productive to support these important shellfish. However, characteristics of the lobster population at the site prior to disposal of dredged material and any population changes over the four years between cessation of dumping in 1970 and collection of the Eatons Neck data in 1974 are unknown.

180. It is recommended that additional studies of the lobster population at Eatons Neck site be conducted to determine potential impacts of any future disposal operations and to determine the feasibility of developing additional productive lobster habitat out of dredged material.

181. Commercially important fish species such as winter flounder ranged from equal to greater abundance in the trawl catches at disposal

site stations as compared to reference station EF3. The disposal site generally accounted for the largest fish catches. Thus it appears that the Eatons Neck disposal site constitutes viable fish habitat. However, the distribution and abundance of fishes exhibited pronounced spatial and temporal variation. This variation in concert with the small number of sampling stations and lack of replicate samples makes these conclusions tentative.

REFERENCES

1. Boyd, M. B., et al., "Disposal of Dredged Spoil Problem Identification and Assessment of Research Program Development," Technical Report H-72-8, November 1972, U. S. Army Engineer Waterways Experiment Station, CE.

2. Riley, G. A., "Review of the Oceanography of Long Island Sound," 1955, Deep Sea Res. Supply, Vol 3:224-238.

3. Riley, G. A., "Environmental Control of Autumn and Winter Diatom Flowering in Long Island Sound," 1959, _In_: Sears, M. E., (Ed.) International Oceanography Congress, Preprint AAA, Washington, D.C., pp 850-851.

4. Harris, E., "The Nitrogen Cycle in Long Island Sound," 1955, Bull. Bingham Oceanography Collection 17(1):31-65.

5. Riley, G. A., "Hydrography of the Long Island Sound and Block Island Sound," 1952, Bull. Bingham Oceanography Collection (3).

6. Riley, G. A., and Conover, S. M., "Oceanography of Long Island Sound," 1952-1954, II Chemical Oceanography - 1956, Bull. Bingham Oceanography Collection, Vol 15, 47-61.

7. Riley, G. A., "Energy, Environment and Planning," 1971, The Long Island Sound Region proceedings of a conference held at Brookhaven National Lab., pp 67-78, Biology of Long Island Sound.

8. Clifford, H. T., and Stephenson, W., _An Introduction to Numerical Classification_, 1975, Academic Press.

9. Boesch, D. F., "Application of Numerical Classification in Ecological Investigations of Water Pollution," Tech. Rept. No. EPA-600/3-77-033, March 1977, U. S. Environmental Protection Agency.

10. Odum, E. P., _Fundamentals of Ecology_, 3rd Edition, 1971, W. B. Saunders Co., pp 143-154.

11. Scheffé, H., _The Analysis of Variance_, 1959, John Wiley & Son, Inc., London and Sidney, pp 55-87.

12. Sallenger, A. H., Goldsmith, V., and Sutton, C. H., "Bathymetric Comparisons: A Manual of Methodology, Error Criteria and Techniques," 1975, Special Report No. 66, Virginia Institute of Marine Sciences, Gloucester Point, Virginia.

13. Pagenkopf, J. R., and Bigham, G. N., "Water Quality Evaluation, Western Long Island Sound," prepared for the Nassau-Suffolk Regional Planning Board by Tetra-Tech., Inc., May 1977.

14. Hardy, C. D., and Weyl, P. K., "Hydrographic Data Report: Long Island Sound - 1970, Part 1," Technical Report No. 6, Marine Sciences Research Center, SUNY, Stony Brook, N.Y., 1970.

15. Dehlinger, P., Fitzgerald, W. F., Feng, S. Y., Paskausky, D. F., Garvine, R. W., and Bohlen, W. F., "A Determination of Budgets of Heavy Metal Wastes in Long Island Sound," First Annual Report (Parts I and II), the University of Connecticut, Marine Sciences Institute, Groton, Connecticut.

16. Mytelka, A. I., Czachor, J. S., Guggino, W. B., and Golub, H., "Heavy Metals in Wastewater and Treatment Plant Effluents," J. Water Poll. Control Fed., Vol 45, 1973, pp 1859-1864.

17. Chen, M., Canelli, A., and Fuhs, G. W., "Effects of Salinity on Nitrification in the East River," J. Water Poll. Control Fed., Vol 47, 1975, pp 2474-2481.

18. Klein, L. A., Lang, M., Nash, N., and Kirschner, S. L., "Sources of Metals in New York City Watershed," J. Water Poll. Control Fed., Vol 46, 1974, pp 2653-2662.

19. McCrone, A. W., "Sediments from Long Island Sound (New York): Physical and Chemical Properties Reviewed," J. Sed. Petrol., Vol 35, 1965, pp 234-236.

20. Duedall, I. W., O'Connors, H. B., and Irwin, B., "Fate of Wastewater Sludge in the New York Bight Apex," J. Water Poll. Control Fed., Vol 47, 1975, pp 2702-2706.

21. Oakley, S. A., and Duedall, I. W., "Report on Carbon and Nitrogen in Sediment Cores from the New York Bight Apex," unpublished report, dated 25 October 1976, submitted to Marine Ecosystem Analysis (MESA), National Oceanic and Atmospheric Administration, Stony Brook, New York, 1976, pp 7.

22. Kaplan, S., "Chemical and Oxidation - Reduction Potential Studies of Long Island Sound Sediments," unpublished Master's Thesis, New York University, 1961.

23. McCrone, A. W., "The Hudson River Estuary: Sedimentary and Geochemical Properties Between Kingston and Haverstraw, New York," J. Sed. Petrol., Vol 37, 1967, pp 456-475.

24. Presley, B. J., Brooks, R. R., and Kaplan, I. R., "Manganses and Related Elements in the Interstitial Waters of Marine Sediments," Science, Vol 158, 1967, pp 906-910.

25. Brooks, R. R., Presley, B. J., and Kaplan, I. R., "Trace Elements in the Interstitial Waters of Marine Sediments," Geochem. Cosmochem. Acta, Vol 32, 1968, pp 397-414.

26. Duchart, P., Calvert, S. E., and Prince, N. B., "Distribution of Trace Metals in the Pore Waters of Shallow Marine Sediments," Limnol. Oceanogr., Vol 18, 1973, pp 605-610.

27. Turekian, K. K., "Trace Elements in Natural Waters," Annual Progress Report (July 1, 1973 to June 30, 1974 grant period) to Atomic Energy Commission for Grant AT (11-1)-3573.

28. Berner, R. A., "Kinetic Models for the Early Diagenesis of Nitrogen, Sulfur, Phosphorus, and Silicon in Anoxic Marine Sediments," In: The Sea (E. D. Goldberg, Ed.) Wiley-Interscience, New York, 1974, pp 895.

29. Tietjen, J. H., "The Ecology of Shallow Water Meiofauna in Two New England Estuaries," 1968, Oecologia 2 (3):251-291.

30. Wieser, W., "Benthic Studies in Buzzards Bay II. The Meiofauna," 1960, Limnol. Oceanogr. 5 (2):121-137.

31. Wigley, R. L., and McIntyre, A. D., "Some Quantitative Comparisons of Offshore Meiobenthos and Macrobenthos South of Martha's Vineyard," 1964, Limnol. Oceanogr. 9 (4):485-493.

32. Richards, S. W., "The Demersal Fish Population of Long Island Sound," 1963, Bull. of the Bingham Oceanographic Collection, Vol 18, Art. 2.

33. Oviatt, A. C., and Nixon, S. W., "The Demersal Fish of Naragansett Bay: An Analysis of Community Structure, Distribution and Abundance," 1973, Estuarine and Coastal Marine Science, pp 361-378.

34. Saila, S. B., (Ed.), "Coastal and Offshore Environmental Inventory, Cape Hatteras to Nantucket Shoals," 1973, Marine Publication Series No. 2, University of Rhode Island.

35. Pierce, Dr. J. B., "An Environmental Survey of Effects of Dredging and Disposal - New London Conn. 6th Quarterly Report," 1976, U. S. Dept. of Commerce, Middle Atlantic Coastal Fisheries Center, IR No. 107.

36. Briggs, Phillip T., and Zanwacki, Chester S., "American Lobsters at Artificial Reefs in New York," January 1976, New York Fish and Game Journal, Vol 21, No. 1.

37. Scarratt, O. J., "An Artificial Reef for Lobsters *(Homarus americanus)*," 1968, Journal of Fisheries Research Board of Canada 25(12).

38. Reese, J. R., and Cobb, S. P., "Feasibility of Constructing Lobster Habitat from Maintenance Dredged Material," 1977, in press. Abstracts of the 57th Annual National Meeting of SAME.

39. Bryan, G. S., "Concentrations of Zinc and Copper in the Tissues of Decapod Orustaceans," U. K. 1968, Journal of Marine Biology Association, Vol 48, pp 303-321.

40. Riley, G. A., "Oceanography of Long Island Sound 1952-1954, II. Physical Oceanography," Bull. Bingham Oceanogr. Coll., Vol 15, 1956a, pp 15-46.

41. Riley, G. A., "Review of the Oceanography of Long Island Sound," Papers in Marine Biology, Supplement to Vol 3 of Deep Sea Research, 1956a, pp 224-238.

Table 1

Volume of Dredged Material Disposed at the Eatons Neck Disposal Site, Long Island Sound

Year	Volume of Dredged Material m^3
1954	
1955	7,721
1956	85,433
1957	100,933
1958	99,374
1959	657,867
1960	269,677
1961	134,933
1962	194,339
1963	3,906,652
1964	2,121,799
1965	140,124
1966	1,011,120
1967	433,418
1968	451,651
1969	102,902
1970	38,072
1971	84,859
1972	
1973	
Total	9,840,874

Table 2

Frequency of Flow Velocity Occurrence at Station E N 1,

20-m Depth, Eatons Neck Disposal Site,

10-20 September 1974

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0											1.46*	98.52
0 - 5	1.01	0.80	1.46	1.01	1.01	1.57	1.80	2.25	2.13	2.47	15.51	83.03
5 - 10	0.12	0.56	1.01	1.24	2.25	2.13	5.62	5.40	4.16	1.12	23.61	59.03
10 - 15	0.22	0.34	2.02	1.91	0.45	0.12	1.24	5.40	1.70	0.45	13.85	45.57
15 - 20	0.00	0.00	2.36	1.70	0.00	0.12	0.22	3.60	0.80	0.00	8.80	36.77
20 - 25	0.00	0.22	4.16	1.91	0.00	0.00	0.12	4.04	0.45	0.00	10.90	25.87
25 - 30	0.00	0.00	2.58	0.45	0.00	0.00	0.12	4.72	0.67	0.00	8.54	17.33
30 - 35	0.00	0.00	2.36	0.22	0.00	0.00	0.00	4.16	0.12	0.00	6.86	10.47
35 - 40	0.12	0.00	0.91	0.00	0.00	0.00	0.00	5.40	0.00	0.00	6.43	4.04
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37	0.00	0.00	3.37	0.67
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.67	0.00
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.47	1.92	16.86	8.44	3.71	3.94	9.12	39.01	10.03	4.04	100.00	

Note: Total number of observations = 890

* No directions assigned to 0 speed (there were 13 zero-speed readings).

Table 3

Frequency of Flow Velocity Occurrence at Station E N 3,

26-m Depth, Eatons Neck Disposal Site,

9-20 September 1974

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0												
0 - 5	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.00	0.37	0.89	99.11
5 - 10	0.88	1.01	0.63	0.13	0.88	0.88	1.39	1.52	0.76	0.37	8.45	90.66
10 - 15	1.77	2.15	0.76	1.64	3.79	3.66	1.39	2.78	3.54	1.77	23.25	67.41
15 - 20	2.27	3.28	1.77	1.01	2.65	3.16	1.64	1.26	0.37	0.63	18.04	49.37
20 - 25	0.51	5.18	2.02	1.01	0.63	2.53	3.91	0.25	0.13	0.37	16.54	32.83
25 - 30	0.00	4.04	1.64	0.00	0.00	0.63	4.67	0.37	0.00	0.00	11.35	21.48
30 - 35	0.13	2.15	0.88	0.00	0.00	0.13	3.16	0.00	0.00	0.00	6.45	15.03
35 - 40	0.00	0.76	0.13	0.00	0.00	0.00	2.40	0.13	0.00	0.00	3.42	11.61
40 - 45	0.00	0.37	0.25	0.00	0.00	0.00	4.04	0.00	0.00	0.00	4.66	6.95
45 - 50	0.00	0.13	0.00	0.00	0.00	0.00	1.52	0.00	0.00	0.00	1.65	5.30
>50	0.00	0.00	0.00	0.00	0.00	0.00	5.30	0.00	0.00	0.00	5.30	0.00
Total	5.56	19.07	8.08	3.79	8.08	11.12	29.55	6.44	4.80	3.51	100.00	

Note: Total number of observations = 792

Table 4

Frequency of Flow Velocity Occurrence at Station E N A

21-m Depth, Eatons Neck Disposal Site,

31 October - 12 December 1974

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0											5.60*	94.40
0 - 5	2.25	6.04	5.68	0.83	1.30	1.10	6.51	4.26	1.85	1.89	31.71	62.69
5 - 10	0.24	4.89	3.04	1.10	0.24	0.24	4.78	3.59	1.22	0.16	19.50	43.19
10 - 15	0.32	3.83	4.81	0.32	0.04	0.04	4.30	4.81	0.12	0.00	18.59	24.60
15 - 20	0.00	1.54	2.92	0.08	0.00	0.00	2.13	3.28	0.00	0.00	9.75	14.85
20 - 25	0.00	1.38	1.97	0.08	0.00	0.00	1.70	2.41	0.00	0.00	7.54	7.31
25 - 30	0.00	0.83	1.38	0.00	0.00	0.00	1.97	2.13	0.00	0.00	6.31	1.00
30 - 35	0.00	0.05	0.12	0.00	0.00	0.00	0.47	0.36	0.00	0.00	1.00	0.00
35 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total	2.81	18.56	19.92	2.41	1.68	1.38	21.86	20.84	3.19	2.05	100.00	

Note: Total number of observations = 2534

* No direction assigned to 0 speed (there were 142 zero-speed readings).

Table 5

Frequency of Flow Velocity Occurrence at Station E N C,

26-m Depth, Eatons Neck Disposal Site,

31 October - 25 November 1974

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0												
0 - 5	0.56	0.72	0.56	0.17	0.21	0.32	0.84	0.78	0.56	0.39	5.11	94.89
5 - 10	1.90	5.52	4.85	1.67	1.23	1.00	4.79	5.80	3.07	1.84	31.67	63.22
10 - 15	1.45	5.52	3.79	0.45	0.17	0.17	3.29	7.64	0.32	0.39	23.19	40.03
15 - 20	0.00	4.07	2.45	0.06	0.00	0.06	2.01	4.57	0.00	0.00	13.22	26.81
20 - 25	0.00	3.34	3.18	0.00	0.00	0.00	1.11	4.63	0.00	0.00	12.26	14.55
25 - 30	0.06	1.73	2.17	0.00	0.00	0.00	1.06	4.96	0.00	0.00	9.98	4.57
30 - 35	0.00	0.06	0.00	0.00	0.00	0.00	0.56	3.40	0.00	0.00	4.02	0.55
35 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.32	0.00	0.00	0.43	0.12
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.12	0.00
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total	3.97	20.96	17.00	2.35	1.61	1.65	13.83	32.16	3.95	2.62	100.00	

Note: Total number of observations = 1794

Table 6

Frequency of Flow Velocity Occurrence at Station E N 5,

32-m Depth, Eatons Neck Disposal Site,

9-20 September 1974

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0												
0 - 5	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.25	0.00	0.38	99.62
5 - 10	0.50	0.75	0.88	1.51	0.25	0.38	0.25	0.13	0.88	0.25	5.78	93.84
10 - 15	1.13	3.40	3.02	1.26	1.89	2.01	0.88	2.14	3.14	1.13	20.00	73.84
15 - 20	1.13	4.53	5.28	1.38	1.13	2.52	1.26	4.28	3.14	1.51	26.16	47.68
20 - 25	0.00	4.65	7.17	0.50	0.00	3.40	2.89	4.03	1.13	0.25	24.02	23.66
25 - 30	0.00	2.01	4.65	0.00	0.00	1.01	1.89	4.15	0.00	0.00	13.71	9.95
30 - 35	0.00	0.38	0.25	0.00	0.00	0.38	2.39	1.76	0.00	0.00	5.16	4.79
35 - 40	0.00	0.00	0.00	0.00	0.00	0.00	1.38	1.13	0.00	0.00	2.51	2.28
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	1.64	0.38	0.00	0.00	2.02	0.26
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.36	0.00
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2.76	15.72	21.25	4.78	3.37	9.70	12.71	18.13	8.54	3.14	100.00	

Note: Total number of observations = 795

Table 7

Frequency of Flow Velocity Occurrence at Station E N A,

22-m Depth, Eatons Neck Disposal Site,

18 December 1974 - 10 January 1975

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0											4.55*	95.45
0 - 5	2.06	5.70	10.25	2.79	1.94	3.34	7.83	7.34	2.25	1.27	44.79	95.45
5 - 10	0.43	3.28	4.79	1.03	0.43	1.64	6.49	3.88	1.46	0.36	23.79	50.66
10 - 15	0.00	2.18	3.28	0.12	0.00	0.06	3.28	2.85	0.24	0.00	12.01	14.86
15 - 20	0.00	1.15	1.46	0.00	0.00	0.00	3.09	1.15	0.00	0.00	6.85	8.01
20 - 25	0.00	0.67	1.64	0.00	0.00	0.00	1.58	1.15	0.00	0.00	5.04	2.97
25 - 30	0.00	0.12	0.55	0.00	0.00	0.00	1.27	0.18	0.00	0.00	2.12	0.85
30 - 35	0.00	0.06	0.06	0.00	0.00	0.00	0.43	0.30	0.00	0.00	0.85	0.00
35 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total	2.49	13.16	22.03	3.94	2.47	5.04	23.97	16.85	3.95	1.63	100.00	

Note: Total number of observations = 1648

* No directions assigned to 0 speed (there were 75 zero-speed readings).

Table 8

Frequency of Flow Velocity Occurrence at Station E N A,

22-m Depth, Eatons Neck Disposal Site,

3 March - 10 April 1975

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0											0.81*	99.19
0 - 5	0.32	1.62	3.34	0.41	0.27	0.72	2.34	3.20	0.41	0.27	12.90	86.29
5 - 10	2.07	3.92	3.02	2.07	2.12	1.58	4.55	2.34	2.34	1.85	25.86	60.43
10 - 15	0.50	3.61	4.82	0.99	0.23	0.23	3.38	4.37	1.80	0.46	20.39	40.04
15 - 20	0.00	3.16	4.96	0.09	0.00	0.00	1.94	5.05	0.23	0.00	15.43	24.61
20 - 25	0.00	1.35	4.51	0.00	0.00	0.00	3.07	5.37	0.00	0.00	14.30	10.31
25 - 30	0.00	0.81	2.25	0.00	0.00	0.00	0.99	2.89	0.05	0.00	6.97	3.34
30 - 35	0.00	0.05	0.54	0.00	0.00	0.00	0.54	0.72	0.00	0.00	1.85	1.49
35 - 40	0.00	0.00	0.23	0.00	0.00	0.00	0.54	0.63	0.00	0.00	1.40	0.09
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total	2.89	14.52	23.67	3.56	2.62	2.53	17.44	24.57	4.83	2.58	100.00	

Note: Total number of observations = 2218

* No directions assigned to 0 speed (there were 18 zero-speed readings).

Table 9

Frequency of Flow Velocity Occurrence at Station E N N,

20-m Depth, Eatons Neck Disposal Site,

15 April - 7 May 1975

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0											2.63*	97.37
0 - 5	0.06	0.00	0.94	1.07	0.25	0.19	0.25	1.82	0.25	0.14	4.97	92.40
5 - 10	1.44	0.75	3.01	4.08	3.14	2.38	1.19	4.96	3.58	2.13	26.66	65.74
10 - 15	1.32	2.82	4.83	2.70	2.20	1.19	3.76	6.46	1.51	0.82	27.61	38.13
15 - 20	0.00	1.69	4.20	0.63	0.06	0.19	3.58	4.96	0.50	0.00	15.81	22.32
20 - 25	0.00	1.25	5.83	0.06	0.00	0.00	1.25	5.14	0.00	0.00	13.53	8.79
25 - 30	0.00	0.82	2.51	0.00	0.00	0.00	0.00	2.45	0.00	0.00	5.84	2.95
30 - 35	0.00	0.38	0.94	0.00	0.00	0.00	0.00	0.25	0.00	0.00	1.57	1.38
35 - 40	0.00	0.06	1.19	0.00	0.00	0.00	0.00	0.13	0.00	0.00	1.38	0.00
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total	2.82	7.77	23.45	8.60	5.65	3.95	10.03	26.17	5.84	3.09	100.00	

Note: Total number of observations = 1594

* No directions assigned to 0 speed (there were 42 zero-speed readings).

Table 10

Frequency of Flow Velocity Occurrence at Station E N N,

20-m Depth, Eatons Neck Disposal Site,

9-19 May 1975

Magnetic Compass Direction, deg - Frequency

Speed cm/sec	0 - 36	36 - 72	72 - 108	108 - 144	144 - 180	180 - 216	216 - 252	252 - 288	288 - 324	324 - 360	% Occurence (A)	% Greater than Indicated Speed Interval (100-A)
0											0.21*	99.79
0 - 5	0.14	0.83	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	98.20
5 - 10	2.35	5.39	1.11	0.41	1.45	0.76	0.07	0.21	0.48	0.69	12.92	85.28
10 - 15	2.70	4.84	2.63	2.84	4.98	5.33	1.04	0.83	1.73	1.18	28.10	57.18
15 - 20	0.14	3.18	4.77	1.24	1.73	4.84	1.94	1.80	0.41	0.00	20.05	37.13
20 - 25	0.00	4.77	3.53	0.07	0.48	1.52	6.02	3.18	0.07	0.00	19.64	17.49
25 - 30	0.00	3.04	0.62	0.14	0.00	0.48	6.22	1.73	0.00	0.00	12.23	5.26
30 - 35	0.00	0.35	0.14	0.00	0.00	0.14	1.87	0.41	0.00	0.00	2.91	2.35
35 - 40	0.00	0.41	0.07	0.07	0.00	0.00	1.31	0.07	0.00	0.07	2.00	0.35
40 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.21	0.14
45 - 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
>50	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.00
Total	4.33	22.81	13.42	4.84	8.64	13.07	18.82	8.23	2.69	1.94	100.00	

Note: Total number of observations = 1446

* No directions assigned to 0 speed (there were 3 zero-speed readings).

Table 11

Water Quality and Sediment Chemistry Variables and Analytical Methods Used for the Eatons Neck Study

Variable Sampled	Laboratory Equipment Used	Laboratory Analytical Procedure Followed
	Water Column Chemistry	
Nutrient Analyzed:		
Ammonium NH_4^+	Technicon Autoanalyzer II	Indophenol method
Nitrate NO_3^-	Technicon Autoanalyzer II	Colorimetric procedure
Nitrate NO_2^-	Technicon Autoanalyzer II	Colorimetric procedure
Total phosphate PO_4^{3-}	Technicon Autoanalyzer II	Colorimetric procedure
Silicate $Si(OH)_4$	Technicon Autoanalyzer II	Colorimetric procedure
Urea	Technicon Autoanalyzer II	McCarthy method
Dissolved organic carbon (DOC)	Bechman Organic Carbon Analyzer (Model 915)	Catalytic combustion
Particulate organic carbon	Hewlett-Packard CHN Analyzer (Model 185)	Catalytic combustion
Temperature	Thermistor Sensor	In situ procedure
Dissolved oxygen	YSI Electrode	In situ procedure
Salinity	Bisset-Berman Salinograph	In situ procedure
pH	Corning Model 12 pH meter	In situ procedure
Chlorophyll a (in vivo)	Turner Flourometer (Model 110)	In situ procedure
Chlorophyll a (extraction)	Turner Fluorometer (Model 110)	Trichromatical and fluorometrical

(Continued)

Table 11 (Continued)

Variable Sampled	Laboratory Equipment Used	Laboratory Analytical Procedure Followed
Dissolved and particulate metals (Ag, Cd, Co, Cr, Cu, Hg, Ni, Pb) (Fe, Mn, Zn)	Perkin Elmer Atomic absorption spectrometer (Model 403) heated graphite atomic directly into air-C_2H_2 flame	Details of methods in Appendix B
Suspended matter	Nuclepore filter apparatus	Filtration drying and weighing
Particle-size distribution	Zeiss Particle Size Analyzer (TG2-3)	Photomicrographic techniques
	Sediment Physicochemistry	
Interstitial water analysis		
Nutrients analyzed:		
Ammonium NH_4^+	Same as for water chemistry	Same as for water chemistry
Nitrate NO_3^-	Same as for water chemistry	Same as for water chemistry
Nitrite NO_2^-	Same as for water chemistry	Same as for water chemistry
Total phosphate PO_4^{3-}	Same as for water chemistry	Same as for water chemistry
Silicate $Si(OH)_4$	Same as for water chemistry	Same as for water chemistry
Dissolved Organic Carbon (DOC)	Same as for water chemistry	Same as for water chemistry
Interstitial metals (Cd, Cu, Ni, Pb) (Fe, Mn, Zn)	Same as for water chemistry	Same as for water chemistry
Sediment grain-size distribution	Grain-size sieves and pipettes	Sieve-pipette method

(Continued)

Table 11 (Concluded)

Variable Sampled	Laboratory Equipment Used	Laboratory Analytical Procedure Followed
Particulate carbon and nitrogen	Same as for water chemistry	Same as for water chemistry
Total sulfides	Titration	Titrimetric (iodine) methods
Percent water	--	Gravimetrical
Clay-fraction mineralogy	X-ray	X-ray defraction
Bulk mineralogy	X-ray	X-ray defraction
Heavy metals of bulk samples (Ag, Cd, Co, Ci, Cu, Fe, Hg, Mn, Ni, Pb, Zn)	Same as water chemistry	Digestion the same as water chemistry
Total cation exchange capacity (TCEC)	--	Cations exchanged for NH_4-
Oil and grease	Separatory filter apparatus	Simplified ether extraction method

Table 12

Selected Ranges for Water Chemistry Variables, Diurnal Study at Disposal Site D, October 1974

Variable	Depth, m	Time	Value
Salinity, o/oo	1	1056	28.10
	29	2236	28.55
Temperature, ^{o}C	1	1056	13.83
	10	1620	14.42
Dissolved Oxygen, mg/ℓ	1	1408	8.51
	10	0837	7.61
Ammonia, μM	20	1408	12.7
	29	2236	0.2
Nitrite, μM	1	1620	2.14
	29	2236	3.25
Nitrate, μM	1	1620	9.26
	20	0837	6.16
Dissolved PO_4^{3-}, μM	10	1620	3.45
	20	0350	3.13
Total PO_4^{3-}, μM	20	1408	2.75
	20	2032	4.50
Silica, μM	20	1408	6.0
	20	2032	16.1
Particulate N, μg/ℓ	10	1056	24
	29	1620	74
Particulate C, μg/ℓ	10	2236	120
	29	1620	768
Chlorophyll _a_, μg/ℓ	1	1620	6.32
	10	0837	1.32

Table 13

Temporal Variation of the Sediment Texture at Reference Stations A and A1

	Time - Type Material, %											
	4 Nov. 1974				5 Jan. 1975				22 May 1975			
Depth (cm)	Gravel	Sand	Silt	Clay	Gravel	Sand	Silt	Clay	Gravel	Sand	Silt	Clay
					Station A							
0-10	0.00	3.51	66.71	29.71	2.48	26.82	48.94	21.76	0.00	25.88	46.82	27.30
10-30	0.00	2.79	63.90	33.31	0.79	42.99	31.53	24.69	9.35	22.02	39.00	29.58
30-50	0.00	3.21	66.00	30.46	0.26	48.19	29.11	22.44	0.00	47.89	25.04	27.07
50-70	0.00	11.26	64.99	23.82	0.26	30.93	36.23	32.22	0.08	50.51	26.28	23.13
70-90	0.00	11.26	64.99	23.82								
					Station A1							
0-10					3.05	26.08	38.62	32.25				
10-30					1.91	31.62	35.51	30.96				
30-50					0.68	39.16	31.02	29.14				
50-60					0.35	45.92	31.99	21.74				

Table 14

Sediment Texture at Reference Station A

and Disposal Site DSA

		Depth, cm - % of Material		
Material	Location	0-10	10-30	30-50
Gravel	Reference Station A	0.00	9.35	0.00
	Disposal Site DSA	1.02	0.11	0.12
Sand	Reference Station A	25.88	22.02	47.89
	Disposal Site DSA	7.78	5.87	6.20
Silt	Reference Station A	48.82	39.00	25.04
	Disposal Site DSA	77.55	66.66	62.56
Clay	Reference Station A	27.30	29.58	27.07
	Disposal Site DSA	13.65	27.37	31.12

Table 15

Ranges of pH in Water and Sediments at Eatons Neck Disposal Site

Date	pH	
	Water	Sediments
November 1974	7.8-8.1	7.4-7.9
December 1974	7.8-8.3	-
January 1975	8.0-8.1	6.1-7.8
February 1975	7.8-7.9	-
March 1975	7.7-8.3	-
April 1975	8.1-8.4	7.2-7.9
May 1975	7.8-8.4	-

Table 16

Sediment pH at Reference Station A and Disposal Site DSA

Location	Depth, cm - pH			
	0-10	10-30	30-50	50-60
Disposal Site DSA-1	7.80	7.72	7.36	-
DSA-2	7.90	7.76	7.70	7.61
DSA-3	7.83	7.70	7.62	-
DSA-4	7.89	7.80	7.53	-
DSA-B	-	-	-	-
DSA-C	-	-	-	-
Average	7.86	7.74	7.55	7.61
Reference Station A	7.58	7.52	7.40	7.18

Table 17

Total Organic Carbon at Reference Station A and Disposal Site DSA

Location	Depth, cm - % TOC* 0-10	10-30	30-50	50-60
Disposal Site DSA-1	2.07	1.58	0.69	-
DSA-2	1.87	1.13	1.00	0.88
DSA-3	2.13	1.39	1.24	-
DSA-4	1.96	1.33	1.24	-
DSA-B	1.62	1.79	1.18	-
DSA-C	2.35	2.00	1.42	1.23
Average	2.0	1.5	1.1	1.0
Reference Station A	1.30	0.54	0.60	0.82

* Percent by weight.

Table 18

Total Organic Nitrogen at Reference Station A and Disposal Site DSA

Location	Depth, cm - TON, %* 0-10	10-30	30-50	50-60
Disposal Site DSA-1	0.24	0.19	0.10	-
DSA-2	0.24	0.14	0.13	0.12
DSA-3	0.20	0.17	0.15	-
DSA-4	0.21	0.16	0.15	-
DSA-B	0.20	0.22	0.16	-
DSA-C	0.26	0.14	0.17	0.15
Average	0.22	0.17	0.14	0.14
Reference Station A	0.17	0.10	0.08	0.10

* Percent by weight.

Table 19

Oil and Grease in Sediments at Reference Station A and Disposal Site DSA

Location	Depth, cm - Oil and Grease*			
	0-10	10-30	30-50	50-60
Disposal Site DSA-1	0.11	-	-	-
DSA-2	-	0.08	0.16	0.12
DSA-3	0.16	0.15	0.09	-
DSA-4	0.14	0.21	0.09	-
DSA-B	0.16	0.08	0.19	-
DSA-C	0.29	0.05	0.08	0.03
Average	0.17	0.11	0.12	-
Reference Station A	0.13	0.04	0.03	0.03

* Percent by weight.

Table 20

Cation Exchange Capacity of Sediments from Reference Station A and Disposal Site DSA

Location	Depth, cm - CEC, meq/100 g			
	0-10	10-30	30-50	50-60
Disposal Site DSA-1	27.6	18.0	15.5	-
DSA-2	10.3	16.9	8.7	10.6
DSA-3	99.6	4.3	5.6	-
DSA-4	-	10.0	14.1	-
DSA-B	31.5	18.0	-	-
DSA-C	38.5	17.6	10.6	8.5
Average	41.5	14.1	10.9	9.5
Reference Station A	13.4	4.2	6.4	4.2

Table 21

Total Metal Concentrations in the 0 to 10-cm Layer at Reference Station A and Disposal Site DSA

Location	Metal Concentrations, µg/g									
	Fe	Mn	Hg	Cd	Cu	Ni	Pb	Zn	Cr	Co
Disposal Site DSA-1	1.87	514	0.50	0.9	155.8	23	63	278	100.0	9
DSA-2	2.04	684	0.49	1.0	141.9	26	71	277	98.2	11
DSA-3	1.83	748	0.36	0.4	123.0	21	57	239	52.4	9
DSA-4	1.78	554	0.42	0.4	112.0	21	45	193	78.8	9
DSA-B	2.03	623	0.46	0.6	135.6	24	65	259	102.9	10
DSA-C	1.99	596	0.33	0.8	127.4	23	62	273	89.5	9
Average	1.92	620	0.44	0.7	133	23	60	253	87	10
Reference Station A	1.52	485	0.33	0.6	96.1	17	51	185	62.4	9

Table 22

Interstitial Metal Concentrations at Reference Station A and Disposal Site DSA

Location	Metal Concentration, μg/l					
	0-10 cm			10-30 cm		
	Fe	Mn	Zn	Fe	Mn	Zn
Disposal Site DSA-1	53	2930	11	56	2450	15
DSA-2	70	3950	15	35	3100	27
DSA-3	2970	4930	30	140	2970	38
DSA-4	218	2950	11	32	3110	0
DSA-B	84	5570	11	67	4930	15
DSA-C	968	2530	48	21	2390	17
Average	727	3810	21	59	3158	19
Reference Station A	25	3680	22	20	1500	20

Table 23

Concentration of Ammonia in the Interstitial Waters at Reference Station A and Disposal Site DSA

Location	Depth, cm - Ammonia, μM			
	0-10	10-30	30-50	50-60
Disposal Site DSA-1	670	890	700	-
DSA-2	750	750	830	650
DSA-3	520	510	480	-
DSA-4	520	630	690	-
DSA-B	870	680	650	660
DSA-C	760	700	550	-
Average	680	690	650	660
Reference Station A	360	400	280	300

Table 24

Phosphate in Interstitial Water at Reference Station A and Disposal Site DSA

Location	Depth, cm - Phosphate, μM			
	0-10	10-30	30-50	50-60
Disposal Site DSA-1	72.8	129.8	137.5	-
DSA-2	94.8	78.8	102.5	135.5
DSA-3	65.8	87.8	85.3	-
DSA-4	49.5	172.0	128.5	-
DSA-B	212.5	126.3	57.8	-
DSA-C	25.8	87.5	100.3	103.3
Average	87	114	102	119
Reference Station A	45.8	63.8	45.8	46.3

Table 25

Percent Sand in Sediment at Benthic Sampling Stations

Date	Station - Percent Sand								
	Mud Stations					Budd Reef Stations		Cable and Anchor Reef Stations	
	EB1	EB2	EB3	EB4	EB5	EB6	EB9	EB7	EB8
October 1974	4	7	8	36	14	47	84	90	79
December 1974	11	30	9	27	11	70	74	87	90
January 1975	21	2	8	65	19	19	19	61	95
February 1975	18	15	15	21	54	37	92	71	93
April 1975	14	10	8	13	5	72	42	75	53

Table 26

Statistical Comparisons of Macrofaunal Total Density and Number of Taxa at Disposal Site and Reference Stations*

Variable	Assemblage	Time of Sampling	Statistical Comparisons ($P < 0.05$)**
Total Density	Mud	December	EB1 ≡ EB2 ≡ EB4 ≡ EB11 ≡ EB12
			EB3 ≡ EB2 ≡ EB1 ≡ EB4
			EB3 > EB11 ≡ EB12[†]
		January, February, April	No significant difference among stations
	Sand	December	No significant difference among stations
		January	EB8 ≡ EB10 > EB7
		February	No significant difference among stations
		April	EB7 ≡ EB8 < EB10
Number of Taxa	Mud	December	EB3 > EB1 ≡ EB11 ≡ EB12
			EB1 ≡ EB2 ≡ EB4 ≡ EB11 ≡ EB12
			EB3 ≡ EB2 ≡ EB4
		January, February	No significant difference among stations
		April	EB1 > EB3 ≡ EB12
			EB1 ≡ EB2 ≡ EB4 ≡ EB11
			EB2 ≡ EB3 ≡ EB2 ≡ EB4 ≡ EB11 ≡ EB12
	Sand	December	No significant difference among stations
		January	EB8 > EB7 ≡ EB10
		February	No significant difference among stations
		April	EB10 > EB7 ≡ EB8

* Disposal site stations were EB1, EB2, and EB4 for the mud assemblage and EB7 and EB8 for the Cable and Anchor Reef sand assemblage. Reference stations were EB3, EB11, and EB12 for the mud assemblages and EB10 for the Cable and Anchor Reef sand assemblage.

** Scheffé's method of linear contrast used.

† The > sign indicates a statistically significant greater value at the 5-percent level of probability.

Table 27

Statistical Analysis for Length of Winter Flounder
Collected for the Eatons Neck Aquatic Disposal Site
November 1974 - June 1975

Station	Parameter	Date Sampled						
		23 Dec 74	22 Jan 75	21 Feb 75	2 Apr 75	15 Apr 75	28 Apr 75	14 May 75
EF1	Mean length	163	117	119	-	165		
	Standard deviation	34	45	42	-	41		
	Median length	167	100	108	-	182		
	Maximum length	264	254	251	-	217		
	Minimum length	90	60	63	-	89 > 1		
	Upper 95% limit	170	126	127	-	188		
	Lower 95% limit	155	108	110	-	142		
	Number in sample	90	105	95	-	15		
EF2	Mean length	148	122	-	-	-		
	Standard deviations	47	40	-	-	-		
	Median length	153	115	-	-	-		
	Maximum length	207	230	-	-	-		
	Minimum length	75	50	-	-	-		
	Upper 95% limit	174	129	-	-	-		
	Lower 95% limit	122	115	-	-	-		
	Number in sample	15	115	-	-			
EF3	Mean length	182	159	132	172	-	185	169
	Standard deviation	53	52	48	40	-	22	44
	Median length	178	150	117	170	-	188	169
	Maximum length	380	275	244	290	-	215	230
	Minimum length	71	80	80	80	-	135	95
	Upper 95% limit	193	171	151	181	-	197	197
	Lower 95% limit	170	147	112	162	-	173	141
	Number in sample	79	72	26	72	-	15	12
EF4	Mean length	171	-	143	-	-	143	-
	Standard deviation	38	-	37	-	-	33	-
	Median length	176	-	150	-	-	145	-
	Maximum length	231	-	219	-	-	191	-
	Minimum length	97	-	64	-	-	89	-
	Upper 95% limit	186	-	154	-	-	162	-
	Lower 95% limit	156	-	133	-	-	125	-
	Number in sample	28	-	53	-	-	15	-

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Cobb, Stephen P

Aquatic disposal field investigations, Eatons Neck Disposal Site, Long Island Sound; an environmental inventory / by S. P. Cobb ... [et al.]. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

94, [24] p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-6)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit No. 1A06.

Appendices A-F published separately.

References: p. 91-94.

1. Dredged material. 2. Dredged material disposal. 3. Eatons Neck disposal site. 4. Environmental effects. 5. Field investigations. 6. Sedimentation. 7. Waste disposal sites. I. Carroll, Joe H., joint author. II. Granat, Mitchell Allen, joint author. III. Holliday, Barry W., joint author. IV. Klehr, E. H., joint author. V. Reese, J. R., joint author. VI. United States. Army. Corps of Engineers. VII. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-6.

TA7.W34 no.D-77-6